SPECIAL ISSUE

VOTE ON THE CENTURY'S 10 HOTTEST SKY EVENTS

Astronomy®

HDG 08070

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As Our Star Heats Up Our Planet Will Fry

ESCAPE

We Must Leave Earth Sooner than You Think

Millennial Fever: Y Celebrate?

A Guide to Infant Stars

How Solar Storms Can Change Your Life

01>

0 75470 08070 8

Now two ETX apertures!

ETX-90EC — $595
ETX-125EC — $895

Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

New Fork Mount Designs with Standard-Equipment Dual-Axis Drive Systems: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

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Plus the features that created the ETX revolution:

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

SPECIFICATIONS: ETX-90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

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Meade ETX-90EC: $595 and ETX-125EC: $895. Each complete as shown, with electronic hand controller; plus packing and shipping.

OPTIONAL SYSTEMS*

#497 Autostar Computer Controller (90, 125)	$149
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#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
#774 Hard Carry Case (90)	99.95
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#932 45° Erecting Prism (90, 125)	49.95
#64 Photo Adapter (90, 125)	34.95
Electric Focuser #1244 (90) *or* #1247 (125)	119.95

**see the Meade accessory ad in this issue.*

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Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location ...only *$149!*

ETX AUTOSTAR
RA = 08:04.6
Dec = +36°38
MEADE
ENTER
MODE
GO TO
1
2
3
4
5
6
7
8
9
0
?

The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

Digital readouts of telescope position (continuously in R.A. and Dec.), menu options, glossary, and utility functions.

Precise sidereal-rate tracking in either altazimuth or equatorial modes. For altazimuth tracking, set the telescope on its drive base and perform a quick, easy alignment.

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RS-232 Serial Port: For operation of the telescope through a personal computer, using Meade Epoch 2000® sky software or other sky software using the LX200 protocol.

Plus: over 20 other menu options, including guided tours, major event menus, user-defined terrestrial objects, and much more.

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(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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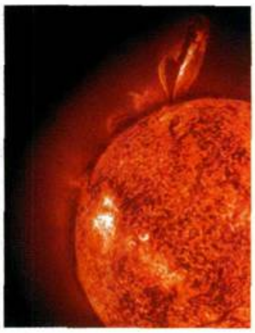
Prices shown are suggested U.S. mail-order retail prices.
Patents pending on ETX-90EC, ETX-125EC, and Autostar.



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Astronomy®

COVER PHOTO: NASA, SOHO, EIT Consortium

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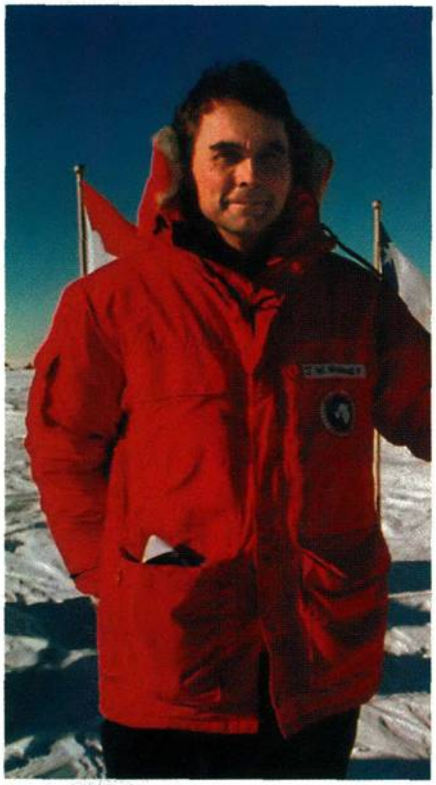

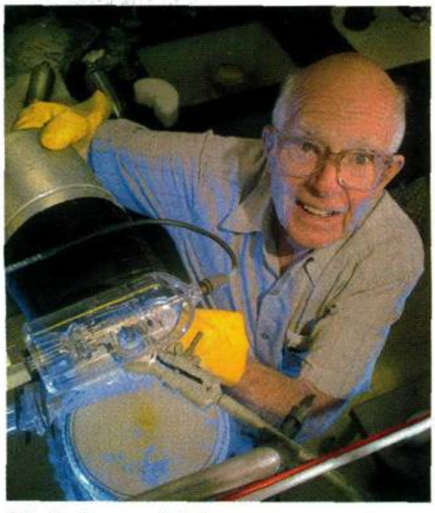

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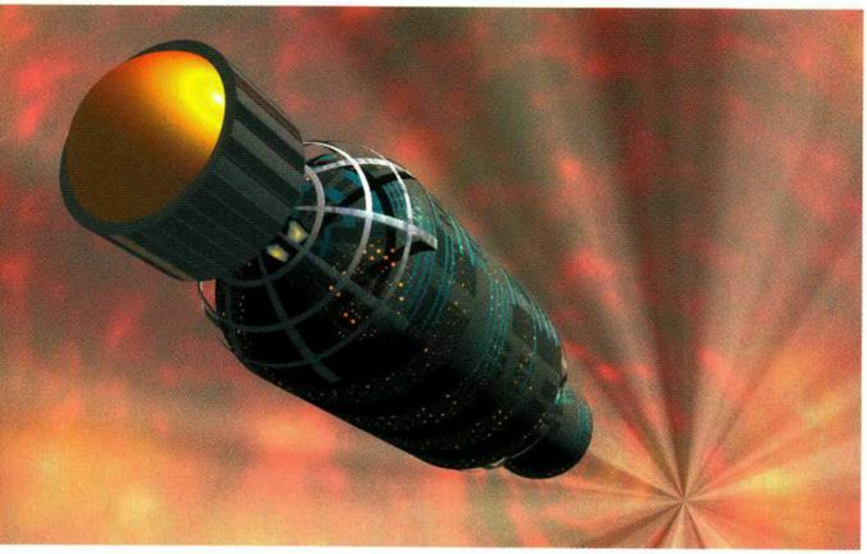

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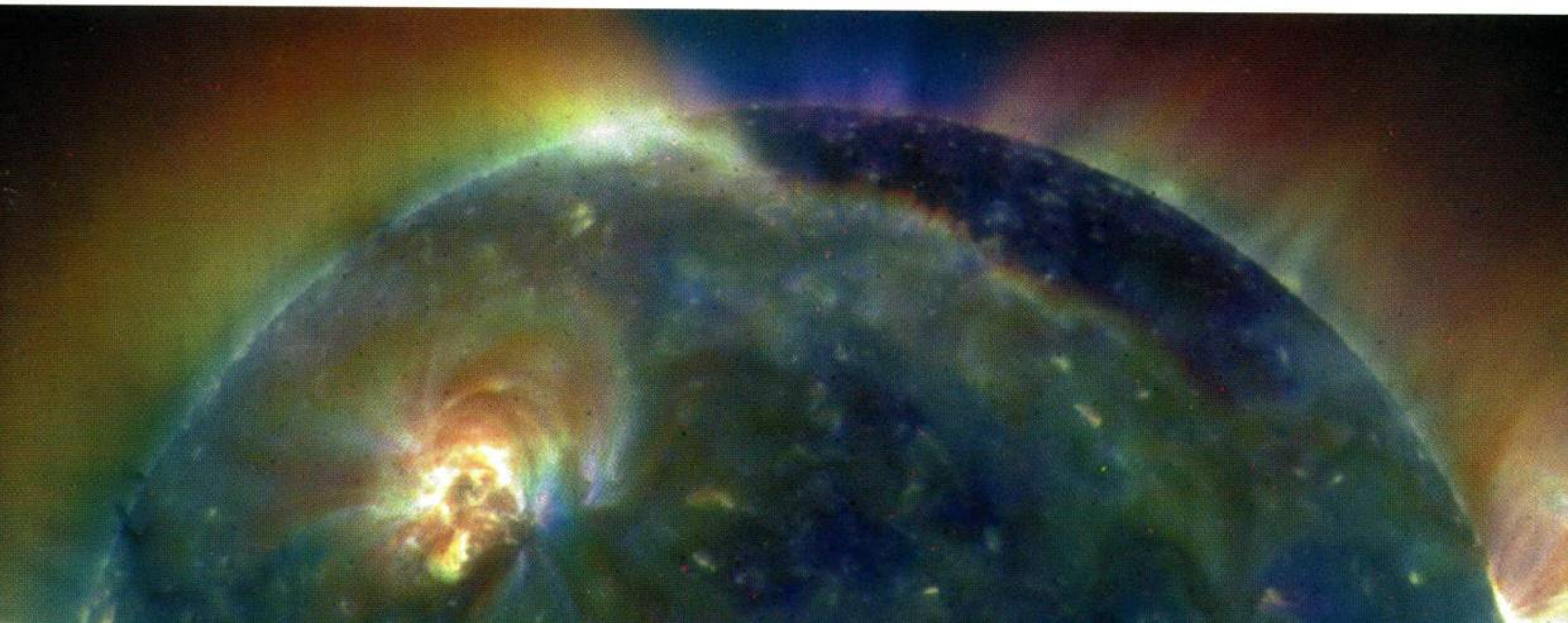


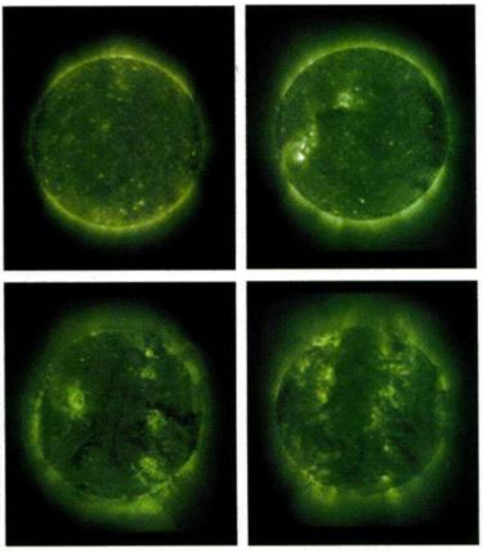
BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Busy Sun

Last autumn at Astrofest in Kankakee, Illinois, associate editor Robert Naeye encouraged me to look at the sun through a hydrogen-alpha filter. He thought I would be so amazed, I would okay the purchase of one for our staff this year. The filter indeed reminded me of a glorious view that can be had for a few thousand dollars.

On this particular day in an Illinois field, the solar prominences made an especially pretty display, two of them forming loops off the limb of the sun. If we were to invest in such equipment, this would be the time to do it.



Courtesy NASA/SOHO/VIRGO Consortium

Clockwise from top left: These ultraviolet SOHO images show an increase in solar activity as the year 2000 solar maximum approaches.

The year will begin with an overactive sun — a solar maximum that will probably continue for most of 2000. This period of solar activity peaks in an 11-year cycle, bringing with it a solar observer's paradise: grand displays of sunspots and solar prominences and beautiful aurorae. It will also charge the atmosphere here on Earth. Solar storms can lift the number of charged particles in its neighborhood, enough to disable some satellites that orbit outside the Earth's magnetosphere. A powerful storm can knock out the electricity of an entire region, as it did in Quebec in March 1989.

The solar maximum will serve as a tiny reminder of our star's power. Though we depend on the sun to sustain life, it also holds dangers larger than melanoma and global warming. One day, perhaps 500 million years from now, Earth will be uninhabitable. The sun will grow too hot.

Senior editor Rex Graham planned and supervised much of this special issue on the evolution of the sun. He worked with artists, designers, other editors, and several freelance writers for the better part of a year to get things just right. To the sun's promise and threats, we dedicate — almost cover to cover — the first issue of the year 2000.

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(+ $65 packing and shipping in the 48 states)

(shown with optional #1702 Drive System)

Model 203SC/500: 8" f/10 Schmidt-Cassegrain Telescope

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Model 102ACHR/300: 4" f/9 Achromatic Refracting Telescope

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LXD 300

Now you can buy a Meade® 8" f/10 Schmidt-Cassegrain Telescope, complete with LXD 300 equatorial mount, rigid full-length aluminum tripod, and accessories for only $795! Or a Meade 4" f/9 Achromatic Refractor, complete, for only $595!

Choose either the Meade 203SC/300, with the exact same optical tube assembly as more expensive Meade 8" Schmidt-Cassegrains, or the Model 102ACHR/300 with its exquisite 4" Meade air-spaced achromatic lens. Both telescopes are equipped with the high-performance Meade LXD 300 equatorial mount with dual-axis aluminum worm gears.

SPECIFICATIONS: Models 203SC/300 and 102ACHR/300 — Each telescope includes 8" f/10 Schmidt-Cassegrain *or* 4" f/9 Achromatic Refractor optical tube assembly with EMC super multi-coatings; LXD 300 equatorial mount with aluminum worm gears, micrometric manual slow-motion controls, and setting circles on both axes; manual control for azimuth alignment; elevation control and scale for polar alignment at latitudes from 15° to 50°; adjustable full-length aluminum tripod with bubble level and accessory shelf; 6 x 30mm achromatic viewfinder; eyepiece-holder (1.25"); #918A diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece (203SC) *or* Series 3000 Plössl 25mm eyepiece (102ACHR); provision for addition of optional #812 Polar Alignment Finder; operating instructions. **8" — $795** (+ $65 P & S); **4" — $595** (+ $55 P & S); **#535 R.A. Motor Drive System...$99; #812 Polar Alignment Finder...$49.**

LXD 500

For even broader capability, use the Meade® high-precision LXD 500 equatorial mounting, 20% larger and with dual-axis bronze worm gears — the finest equatorial mounting available in its price class.

SPECIFICATIONS: Models 203SC/500 and 102ACHR/500— Each telescope includes 8" f/10 Schmidt-Cassegrain *or* 4" f/9 Achromatic Refractor optical tube assembly with EMC super multi-coatings; LXD 500 equatorial mount with oversize bearings, high-precision bronze worm gears, micrometric manual slow-motion controls, and setting circles on both axes; manual control for azimuth alignment; elevation control and scale for polar alignment at latitudes from 15° to 60°; adjustable full-length aluminum tripod with bubble level and accessory shelf; 6 x 30mm achromatic viewfinder; eyepiece-holder (1.25"); #918A diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece (203SC) *or* Series 3000 Plössl 25mm eyepiece (102ACHR); provision for addition of optional #812 Polar Alignment Finder; operating instructions **8" — $895** (+ $65 P & S); **4" — $695** (+ $55 P & S); **#1701 R.A. Motor Drive System** with 4-speed controller...**$145; #1702 Dual-Axis Drive System** with 4-speed controller...**$195**; **#812 Polar Alignment Finder...$49.**

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Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

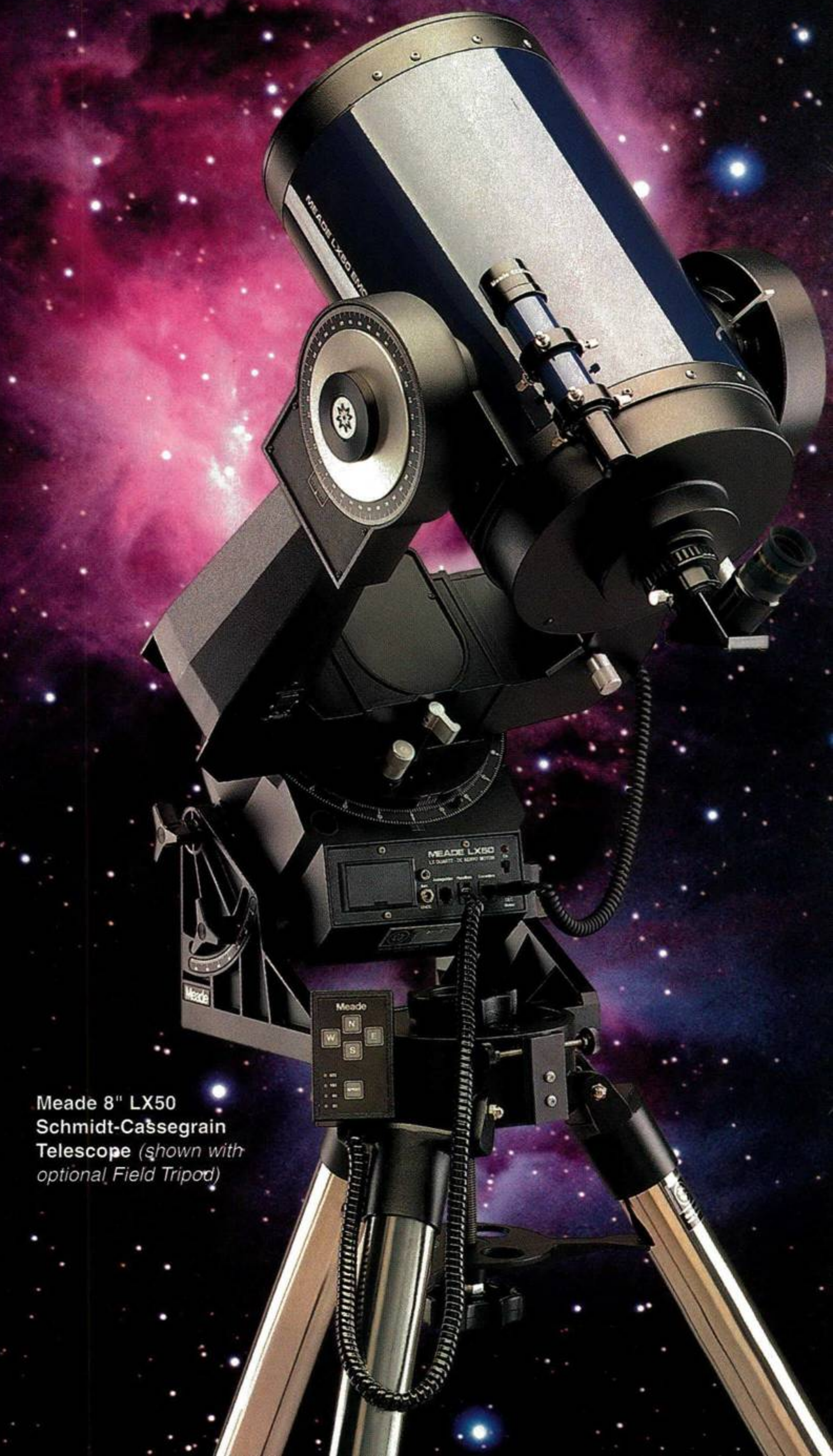
SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. *Standard-equipment includes:*

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

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Now with Series 4000 Super Plössl 26mm eyepiece as *standard equipment!* Consider these features:

Series 4000 SP26mm Eyepiece (1.25"): The premium SP26mm ocular permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities. This $80 eyepiece is now **standard-equipment** on all Meade Dobsonians.

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Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: The same strong, spiral-wound Sonotubes™ used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

$270 Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

2 - **Meade Series 4000 Super Plössl 9.7mm and 26mm** multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
ENTER
MODE
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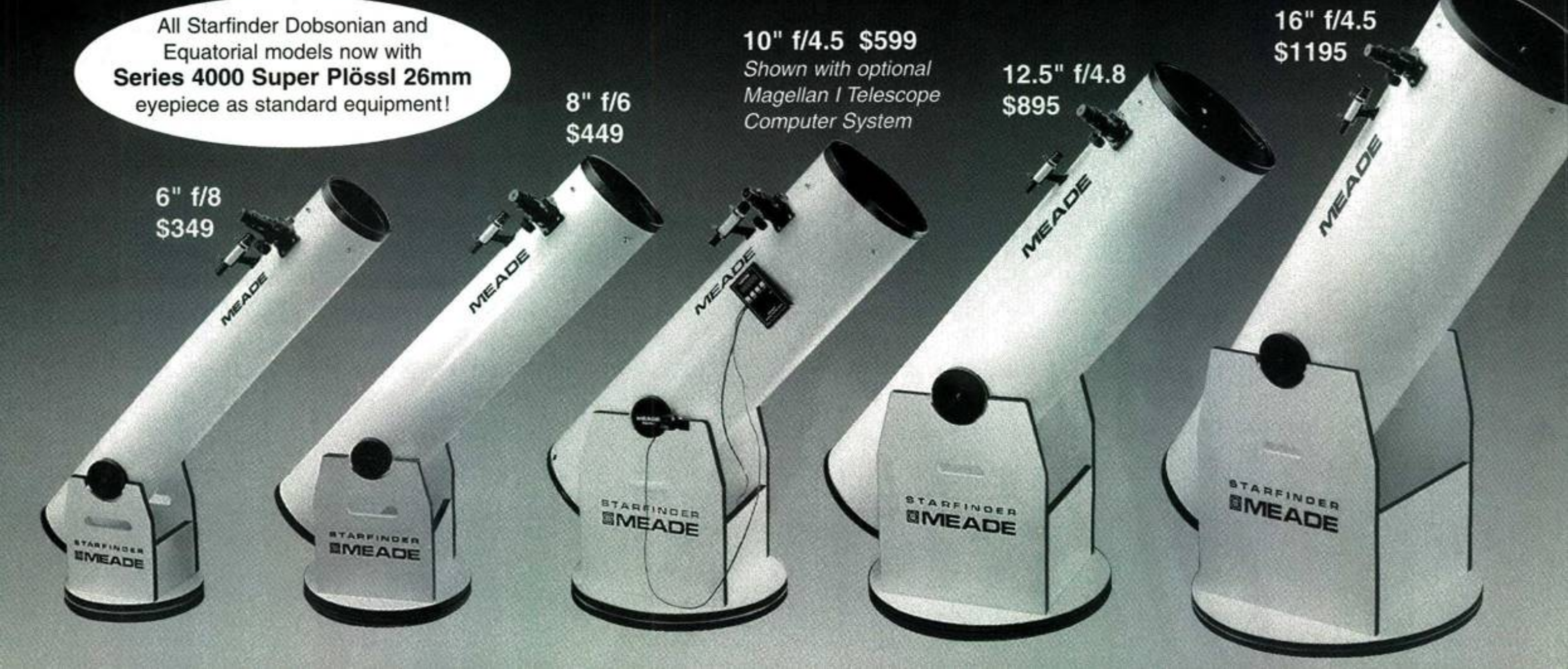
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



MEADE
STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

With DC-powered drive systems for automatic tracking and Series 4000 Super Plössl 26mm eyepiece.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); #637 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

MEADE
ENTER
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MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
COMPUTER CORRECTOR
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

New 120-page 1999-2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
The largest-selling telescopes in the world. ☐ *A NASDAQ company.*
6001 Oak Canyon, Irvine, California 92620 ☐ (949) 451-1450
FAX: (949) 451-1460 ☐ *www.meade.com*

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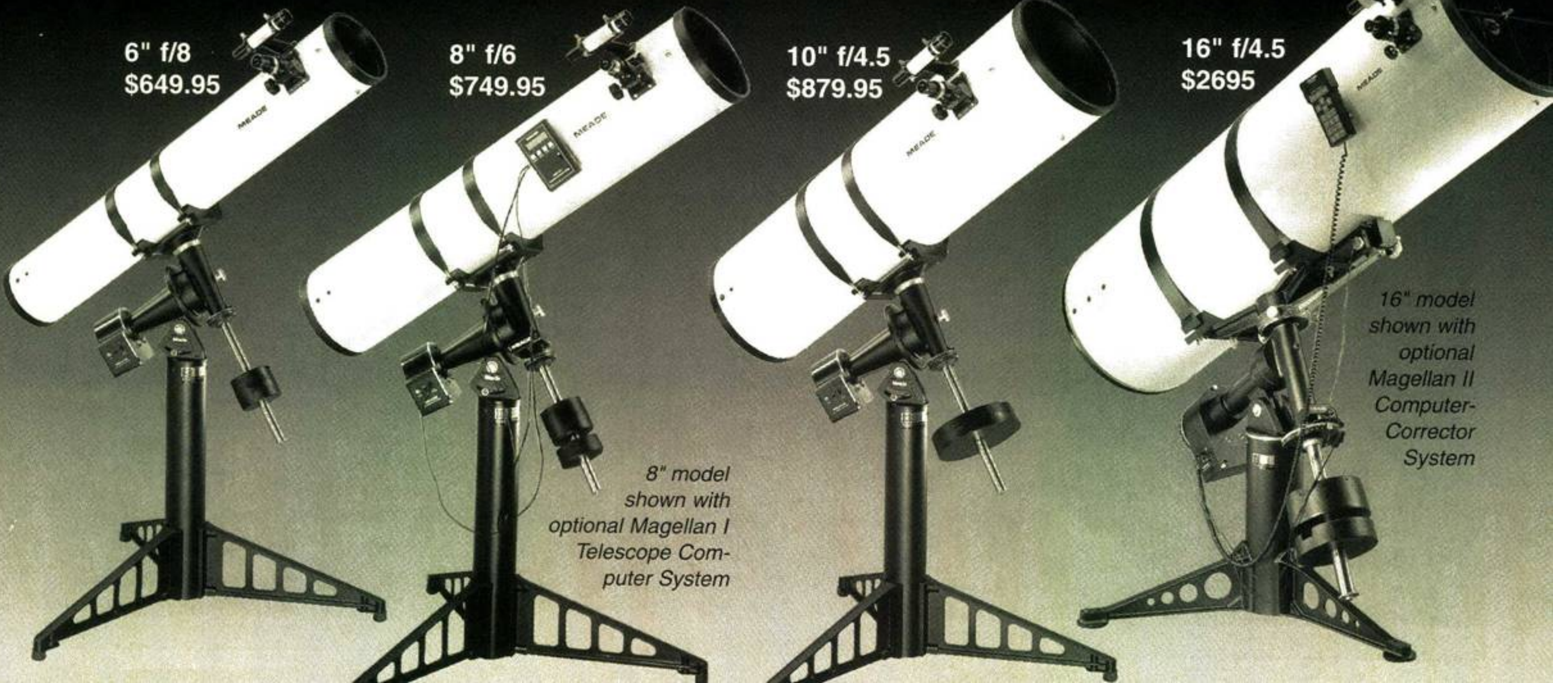
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



6" f/8
$649.95

8" f/6
$749.95

10" f/4.5
$879.95

16" f/4.5
$2695

8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

F/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

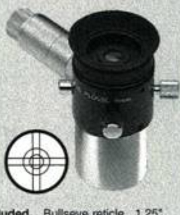
#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

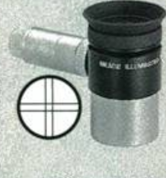
#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

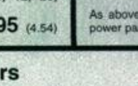


Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

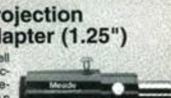
Camera Adapters



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (3.86)

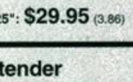
Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

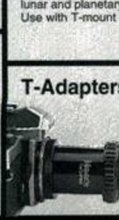
Variable Tele-Extender



For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's



Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

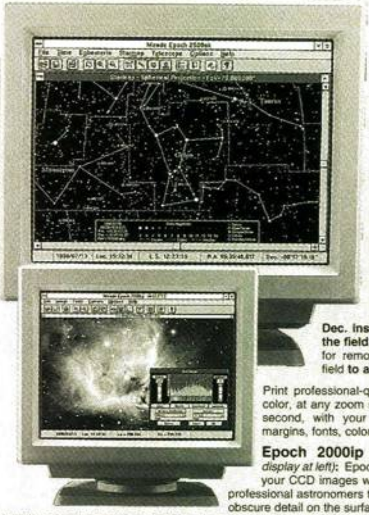
#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

NEW!
MEADE
FLIP-MIRROR SYSTEM
MEADE
PICTOR

#644
MEADE
FLIP-MIRROR SYSTEM

#647
MEADE
FLIP-MIRROR SYSTEM
MODEL 647



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$199**

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

CCD f/3.3 CCD FOCAL REDUCER

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLOESSL
CCD FRAMING

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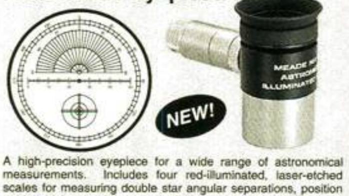

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#774 Case for ETX-90 models: **99.95** (8.58)

#775 for ETX-125EC: **149.95** (13.38)

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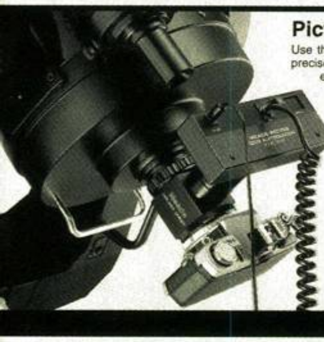

Use the Pictor 201XT to take even the longest exposures, knowing that the telescope will precisely track the object being photographed or imaged. Can be used on any telescope equipped with a dual-axis drive corrector. On Meade LX50 and LX200 Schmidt-Cassegrains and on other telescopes with an "Autoguider" connector the 201XT plugs into the telescope's control panel. On telescopes where the drive corrector is not integrated into the electronics of the telescope itself, the optional #520 Electronic Relay is required. The Pictor 201XT is completely self-contained; no separate control box or PC is required. Used with an off-axis guider or guide telescope, the 201XT automatically locks-on the brightest star in the field (a star that can be as faint as 12th-magnitude), sets its own integration time, and actuates all required dual-axis corrections for superbly guided astrophotographs or CCD images. Incorporates TC-255 CCD chip and operates from 12v. DC auto cigarette lighter plug with 25 ft. power cord, included. **$395.** (7.02)

#520 Electronic Relay: Use with Pictor 201XT on telescopes without autoguider connector or with retrofitted drive corrector. **95.** (5.28)

#541 AC Adapter: For 201XT operation from 115v.AC; includes 25 ft. cord. **35.** (6.56)

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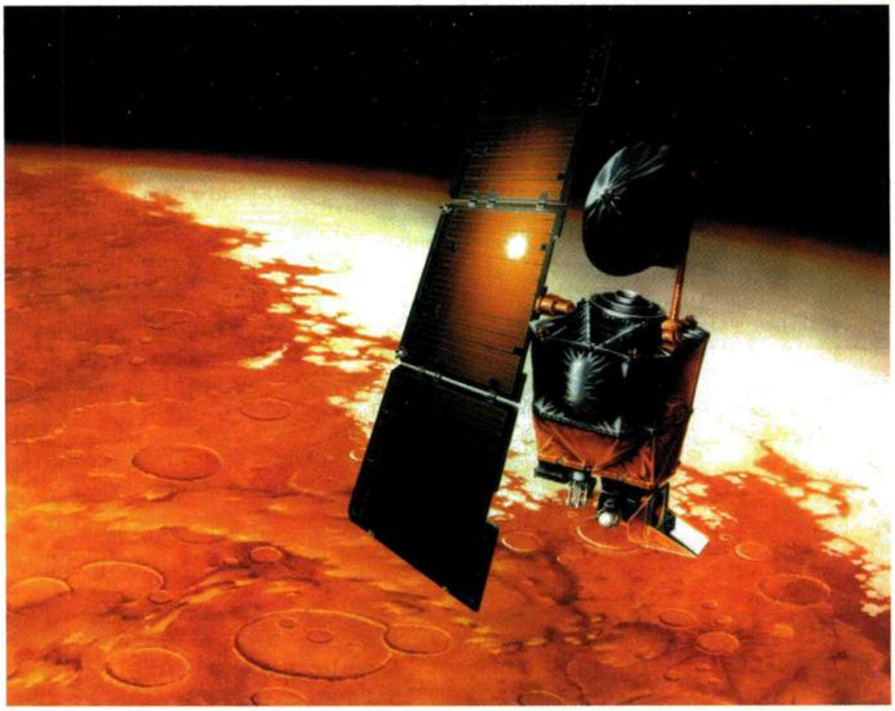

Mars Climate Orbiter, lost in September 1999, was supposed to keep a close eye on the martian surface — but not too close.

NASA/JPL

We have all experienced a tragic loss with the demise of the Mars Climate Orbiter. This is the second of two craft lost trying to reach Mars in the past six years. There may be those who say that whatever martians live there must be to blame, and we should leave Mars alone. Congress continues to threaten to cut a large portion of the space-science budget, when it should be doing just the opposite.

Let's just suppose for a moment that funds had been available for a manned mission rather than a robotic one. The same dangers would have been there, but with one indisputable difference: Humans have the ability to adapt rapidly to hostile and changing situations. Perhaps with a human at the controls, a real-time, split-second reaction could have kept the orbiter from going too deeply into Mars's atmosphere. How many times have we seen humans save the day in space? Apollo 13, ingenious retrievals of wayward satellites by shuttle crews, and countless fixes for the Mir Space Station offer a few examples of how human presence affects space exploration.

Robotic missions will indisputably continue because they offer significant cost savings over manned missions. However, it will be humans that make the incalculable difference. — *Juris Breikss, Elizabeth, Colorado*

Protecting Copernicus

I enjoyed Rosemary Sullivant's article on Copernicus (October 1999) and was impressed by her attention to historical detail. I was surprised, however, at her suggestion that "Perhaps, in an attempt to make Copernicus's ideas more acceptable, Osiander [Andreas Osiander, protestant theologian, proofreader of Copernicus's manuscript] inserted his unsigned introduction." Ms. Sullivant proceeds to relate that this introduction, "in contradiction to Copernicus's intent, asserted that the contents of the book were not meant to be true but only a working hypothesis to explain certain phenomena."

I would suggest that Osiander's motive was not to make the ideas in the book more acceptable but rather to protect Copernicus from the inquisition. In fact, it was common practice at the time that philosophical or scientific writings and statements that contradicted the teachings of the church were tolerated only as long as they were clearly presented as hypotheses, and not as statements of fact. — *Habib Najm, Pleasanton, California*

The Kansas Evolution

Contrary to what you've read, we still can teach all about evolution in the state of Kansas, and of course that includes stellar evolution. The issue is that it is no longer part of the state's standards and will not be tested at the school level. At the college level, nothing has changed. But now local primary and high schools can make their own decisions about what is taught and what is not. A school can decide to teach creationism as a scientific theory. That is unlikely to happen in the city schools since they have dedicated science teachers, but who is going to spend classroom time on something that will not be tested?

Some interesting things are happening though. The National Science Teacher Association (NSTA) teachers' guides have a copyright clause. NSTA is considering denying use of its copyrighted materials in Kansas schools. Similar pressure is coming from the local universities and colleges. Entrance to better schools will require that local schools teach evolution as part of their science courses. Such pressure is influential, and I'm sure that someone is going to put a red line through the school-board decision.

Our local newspaper has been doing a great job in highlighting the

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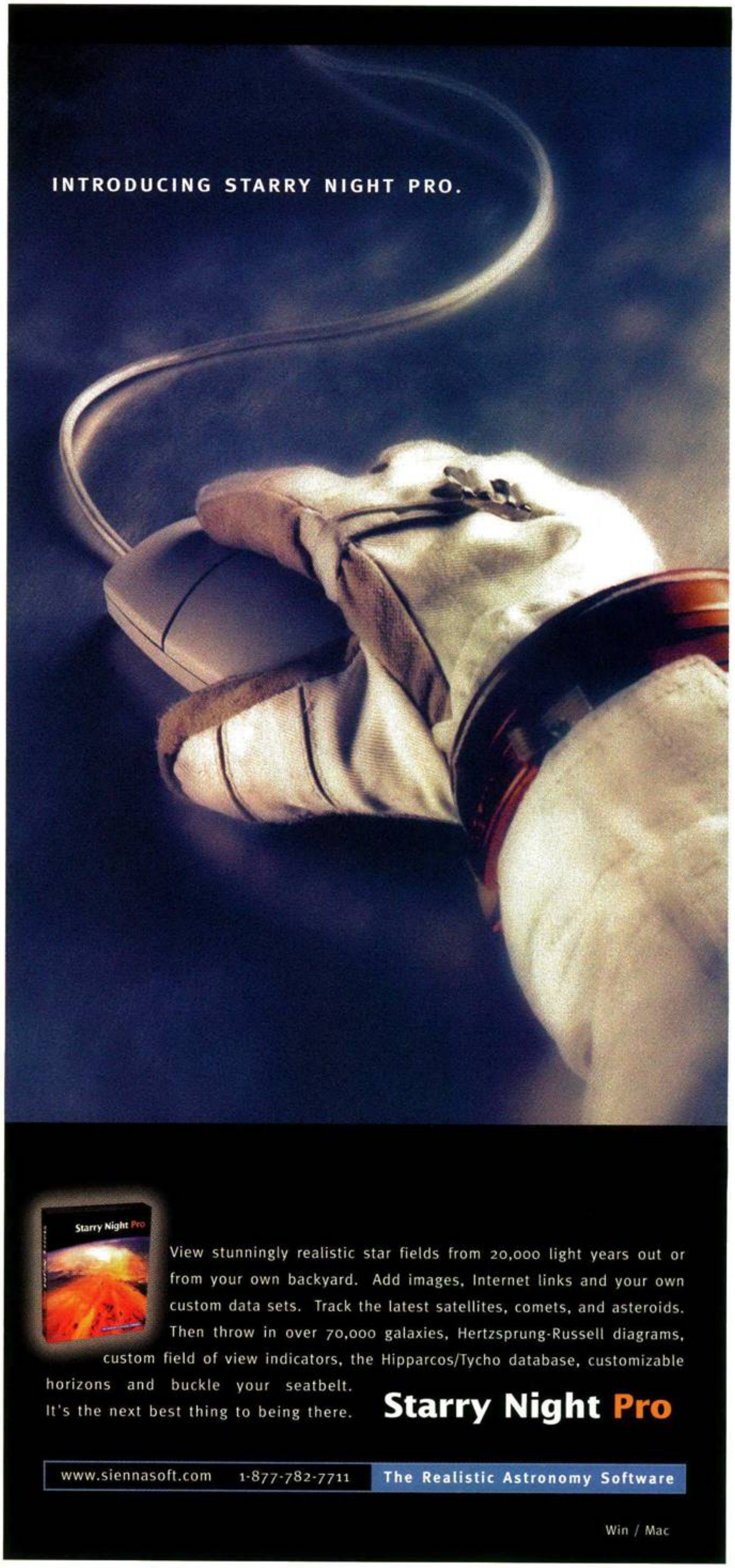

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ridiculous nature of this decision, lambasting the school board for its action. Here's what led to the decision: A small number of creationist board members were denying approval to any curriculum that contained the topic of evolution. Leaving the decision of what to teach to local schools was the compromise that allowed the bill to pass. If the local furor is anything to judge by, the decision will be reversed within the year. But it does show you what a tiny minority can do by influencing politics at the local level.

About $62 million has gone into the development of Exploration Place, the science museum that employs me in Wichita. Our benefactors are committed to making Exploration Place outstanding. They want to offer opportunities for discovery and exploration and to help develop the culture of independent, critical thinkers.

I'm sure that this school-board vote will be seen as a minor blip in the history of Kansas education. Meanwhile, I believe that thousands of science teachers in Kansas eagerly await the opening of Exploration Place (in spring 2000). — *Martin Ratcliffe, Exploration Place, Wichita, Kansas*

Too Hot for Celsius

In his letter "Too Hot or Too Cold" (October 1999, Talking Back), Dennis Garratt wrote that he objected to the use of Fahrenheit measurements for temperatures.

In São Paulo, Brazil, we use Celsius to measure body temperatures. In our country, 36.5° C is a normal body temperature, 38° C indicates that you have a fever, 39° C indicates you have a high fever, and 41° C means you have a fever so high that it might lead to some brain damage.

In summer, São Paulo reaches 90° F, and thank heavens we use –32 in our conversion equation. Otherwise it would be too hot to live here. — *Decio Ros, São Paulo, Brazil*

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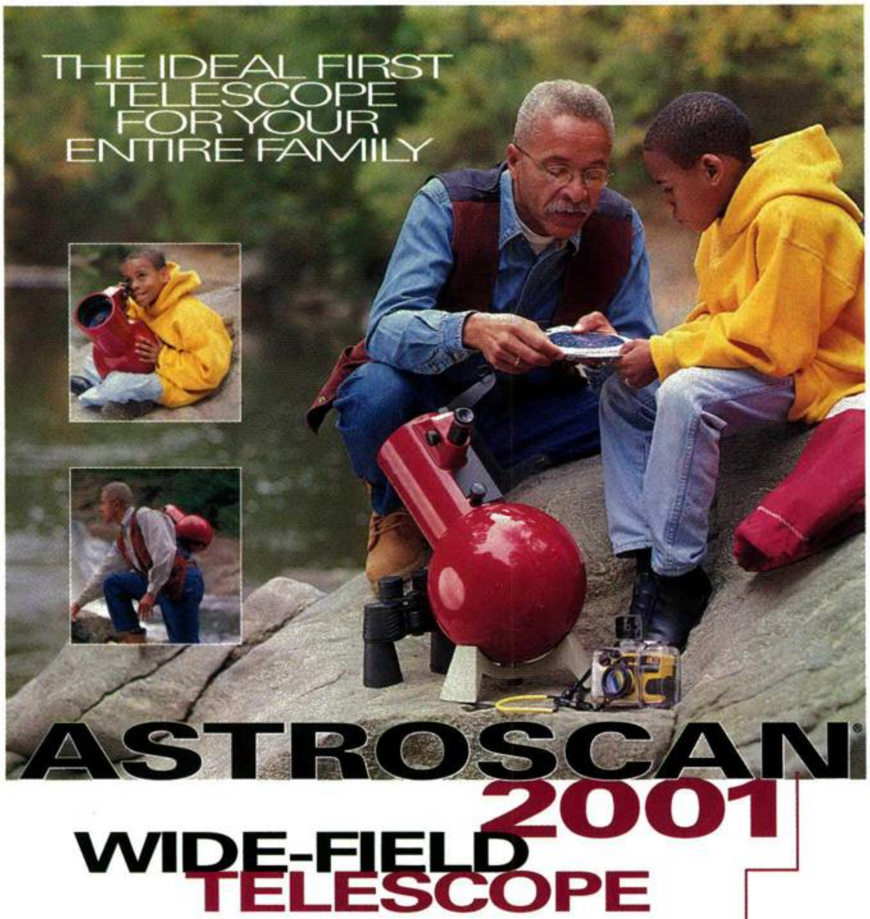

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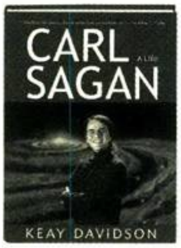
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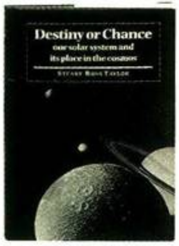
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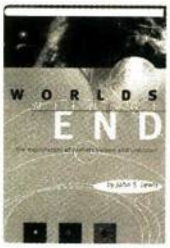

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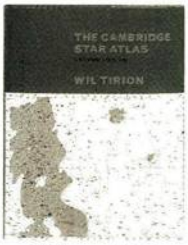
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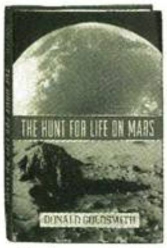
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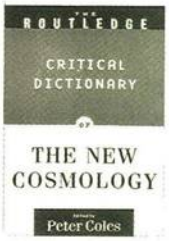
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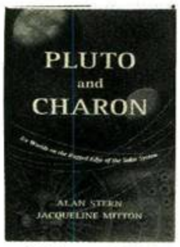
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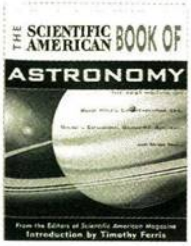
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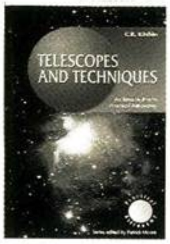
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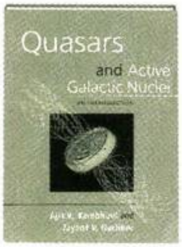
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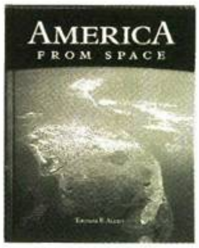
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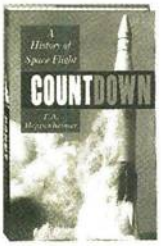
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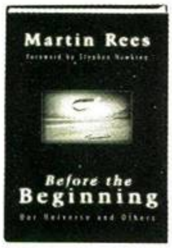
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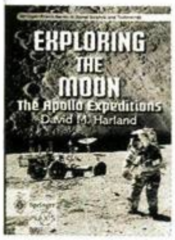
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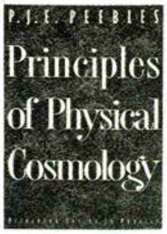
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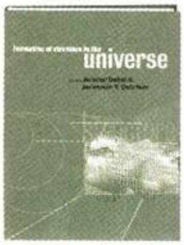

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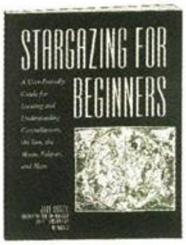
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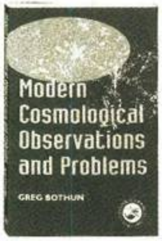
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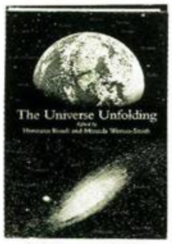
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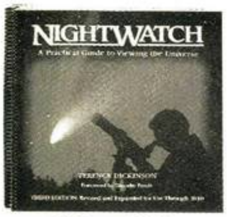
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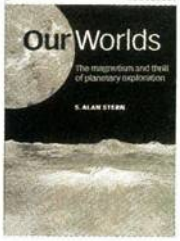
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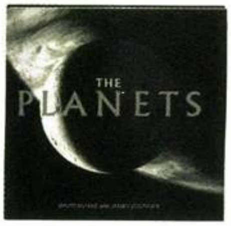
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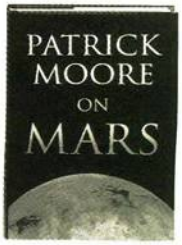
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See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.

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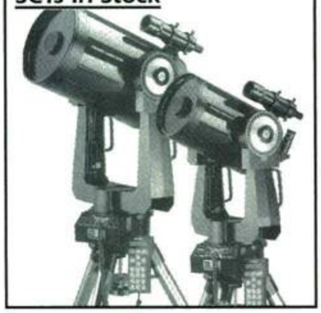

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Magellan computer, specify Dob or Equatorial ($15 P&S) $285; **Lumicon 1 1/4" UHC or O-III** Filter $99.50. **Vinyl covers** to keep dust free (2 req.) for **6" - $10**; for **8" - $15**; for **10" - $20**; for **16" -$35**.

Meade SCT & Maks 3.5"-16"

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8" LX200 w/computer ($65 P&S)	$2795
Wedge for photographing w/8" LX200	$139
7" LX50 f/15 Maksutov w/wedge ($125 P&S)	$1795
10" LX50 f/10 w/wedge, dec. motor, hand controller ($155 P&S)	$1695
10" LX 200 w/ computer ($155 P&S) .	$3195
12" LX 200 (f/10 only) ($215 P&S)	$4495
SuperWedge for photo. w/10", 12" LX200 .	$395
16" LX200 f/10 w/tripod ($385 P&S)	$14,950

LX50 – includes dec. motor, hand controller.

LX 200 - full computer control w/64k mem.

Tripod: Extra for LX 50; included for LX200

Note: Wedge is not needed for visual observing with the LX 200. Select f/10 or f/6.3 (no extra charge) for LX 200.

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Dew Shields	8" $119	10" $129
	12" ... $189	16" $289

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Prominence
Filters

Lumicon Solar Prominence Filter 11/2" Angstrom bandpass. Includes 77mm energy rejection pre-filter. (State telescope type)	$595
3" off-axis metal mask to hold pre-filter .... 8"SCT, $68; 10", $88; C-11, $88; C-14,	$110
2" adapter for C-8. Meade 8-12"	$29.50
Adapter for 1 1/4" or .096" focuser	$22

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40mmF.L., 65°Apparent Field 2"	$299

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5X Powermate boosts magnification 5x	$168
Ranger 70mm f6.8 apchromat w/45° diag.	$685
Pronto 70mmf6.8 w/45° erecting prism	$925
Tele-Vue 85,85mm f/7 APO telescope	$1995
Bino-Vue binocular w/2x correc.	$1030
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32mm Plossl, widest true field in 1 1/4" ..	$110
55mm Plossl, widest possible field	$228
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2" Giant Barlow – 2x	$168
4.8mm Nagler 82° field, 1 1/4 " eyepiece	$175
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15mm Panoptic 1 1/4", 68° field	$210
19mm Panoptic 1 1/4", 68° field	$240
22mm Panoptic 1 1/4"/2", 68° field	$280
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Note: TeleVue warranty may not be valid outside USA

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1 1/2"	2/$2	9 1/2", 10.4"*	$15
2"	2/$2	12 1/2",12 7/8"*	$20
2 1/8"	2/$2	15", 15.6", 16"*	$28
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*Fits Odyssey		21" (Odyssey-II)	$35

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Telescopes and accessories. 10% off! Call for details

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LUMICON'S piggyback mount is ideal for telescopes of 6-16" aperture. It permits both vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER, large telephoto lenses and small telescopes up to about 5 lbs.

Lumicon Adj.Piggyback Mount $59.50

Specify telescope size: 6", 8", 10", 11", 14", 16":

H-ALPHA pass filter

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. *For color, use the LUMICON Deep-Sky (DS) filter.*

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67,72,77mm	$79.00 ..	$399.50
82mm (77mm+adapter)	$89.00 ..	$415.00
Hypered 2415 film, 36 exp		$13.95

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2" adapter for C-70, C-80F, C-102F fluorite	$39.50
2" adapter for C-6, Comet Catcher, Meade 395	$30.00

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T-thread 1 1/4" adapter	$25.00
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**threaded to hold 48mm filters*

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Enhanced Mirrors Boost Telescope Performance

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90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

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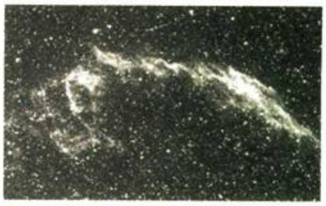

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"The LUMICON O-III proved to be our favorite . . .it gave the greatest contrast gain." *ASTRONOMY, February 1991*

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"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in more than two dozen objects I viewed." *SKY & TELESCOPE, July 1995*

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"LUMICON's H-Beta Filter will show subtle features in emission nebulae that others fail to reveal. It can't be beat for the elusive Horsehead and California Nebulae." *SKY & TELESCOPE, July 1995*

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BEST for Astrophotography!
"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for both color and black and white photography.

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"Based on our tests, we'd recommend a LUMICON Deep-Sky and Oxygen III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for reflection nebulae." *ASTRONOMY, February 1991*

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- Just two stars to align
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SKY VECTOR I™ $299.00
NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349.00
Over 3600 objects! Also included planets and full visual descriptions.

Specify Telescope Type: Meade 4",8", 10",12" SCT, C-8, C-11, Odyssey 8", 10", 12", 17 1/2" alt-azimuth; Meade 6"-16" Dobsonian. Ultima 8", 9 1/4", 11", add $25 C-14 add $75.

Deep Sky Astrophotography | PPF 400 NEW FILM

LUMICON Easy-Guiders™*

Guide off-axis to make lovely astrophotos. All LUMICON Easy-Guider™ off axis guiders have both radial and 360° rotational adjustments for 5x easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide stars. Specify camera and telescope type.

NEWTONIAN Easy-Guiders

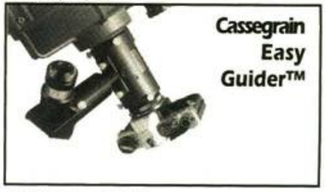
NEWTONIAN Easy-Guider	$189,50
48mm coma corrector/field flattener	$285.00
1.8X multiplier (2" Deluxe Barlow)	$259.00
3x relay diagonal	$99.50
Illuminated recticle eyepiece, pulsed	$119.50
Guider for Hasselblad	$489.00
Guider for Mamiya 645	$259.00

CASSEGRAIN Easy-Guiders
for C-8, Meade 2080, Cynamax 8, includes 50mm achromatic lens for f/6 operation (3x shorter exposures!). Superb rich field viewing too.

Cassegrain Easy-Guider	$249.00
Adapter for Hasselblad	$299.00

Mamiya 645 $119; Pentax 6x7 add $129, Pentax 645 add $149.

*US Pat. 4,448,500



GIANT Easy-Guider
For Celestron 11, C-14 and the 10"-12" Meades. Includes 80 mm clear aperture achromatic lens for edge-to-edge illumination & pinpoint star images. f/ratio adjustable f/4 to f/11. Also yields unmatched rich-field viewing.

Giant Easy-Guider	$395.00

Adapter for Hasselblad $399; Mamiya 645 $149; Pentax 6x7add$139; Pentax 645 add $159.

48mm Deep-Sky Filter ordered with any Easy-Guider, (save $20)	$179.50
Illuminated recticle eyepiece	$119.50
Cable Release	$9.95
Declination motor (state scope type)	$109.00

Film Hypersensitization Kits*
LUMICON Hyper-Kits™ yield 3-15x film speed gain in long exposures. They are safe and simple to use. Easy Hyper-Kit™ includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flamable forming gas and a hand operated vacuum pump. **US Pat. 4,473,636*

Model 300 Hyper-Kit sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds	$325
Model 600 Hyper-Kit Like the Model 300, but also sensitizes 120/220 larger film and small glass plates.	$395
Model 1200 Hyper-Kit is for 4x5" plates and film up to 5x7" . Has 2 gas cylinders & temperature controller.	$595
Temperature controller for any kit	$75
Electric Vacuum Pump, Model R-10	$325

Try PPF Hypersensitized Film
LUMICON Hypersensitized film: essential for good deep-sky astrophotography. (Deduct 10% for 3 or more rolls.)

Kodak PPF-400 THE BEST!, 36exp.	$14.95
2415 Ultrafine B&W, red sensitive, 36 exp.	$13.95
Fuji G800 Fine Grain color neg. 24 exp.	$13.95
Ektachrome1600, fast slide film, 24 exp.	$19.95
Fujichrome RD-100, fine grain slide, 24 exp.	$12.95
D-19 B&W Developer, 1 gal.	$8.50
Portra 400, 120 size VC or NC	$19.95

Meade & Celestron

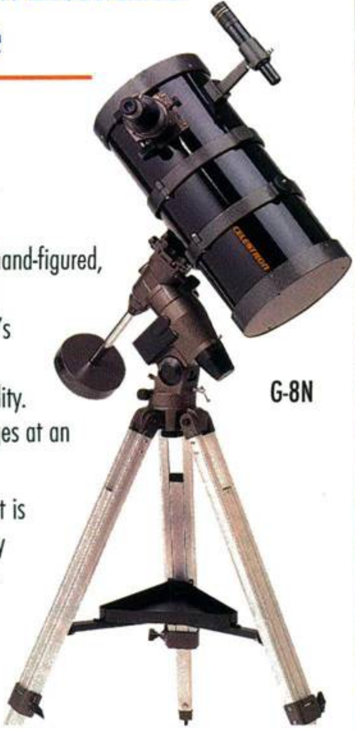
Lumicon carries a full line of
Meade & Celestron Telescopes & Accessories
All at competitive prices & with FAST delivery
California residents add 8.25% sales tax

G-8

CELESTRON TELESCOPES

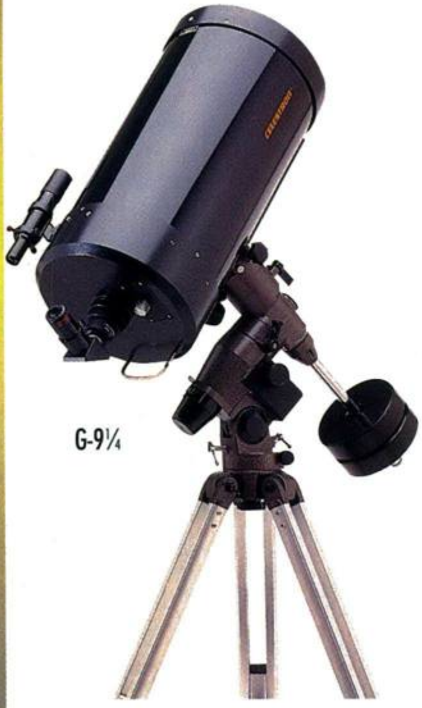
SCHMIDT-CASSEGRAIN • REFRACTOR • NEWTONIAN

Large Aperture Telescopes with Unequaled Optical Excellence + a Superb German Equatorial Mount = Real Value


G-8N

OPTICS: **G-8 Telescope** – 8" f/10 Schmidt-Cassegrain
G-9¼ Telescope – 9¼" f/10 Schmidt-Cassegrain
G-8N Telescope – 8" f/5 Newtonian
CR-150 Telescope – 6" f/8 Refractor

Both of the Schmidt-Cassegrain systems are made in the U.S.A. and feature hand-figured, diffraction-limited optics along with Starbright® multicoatings. The fast (f/5) Newtonian is made to Celestron's uncompromising standards. The Newtonian's proprietary optical design incorporates an auxiliary correcting lens to reduce aberrations, flatten the field and allow a short tube design for added portability. The 6" refractor is a fully multicoated achromat which delivers excellent images at an incredibly low price.


G-9¼

MOUNT: All four telescopes use the CG-5 German mount. The CG-5 mount is the newest generation of Celestron's German mounts which was designed by Celestron. Now, preloaded bearings in R.A. are standard (for added smoothness) which competitive models do not offer. Both axes of the equatorial mount have precision worm gears for extremely smooth motion and excellent tracking accuracy.

This heavy-duty mount easily delivers jitter-free images and the sturdy adjustable height aluminum tripod has excellent damping characteristics. A convenient deluxe accessory tray adds to the stability of the system.

CR-150

ACCESSORIES: Numerous accessories are available for these telescopes. Included as standard eyepieces – 25mm SMA - 1¼" (81x) on the G-8, 26mm Plössl - 1¼" (90x) on the G-9¼, 20mm Plössl - 1¼" (50x) on the G-8N, and 20 mm Plössl - 1¼" (60x) on the CR-150. The standard finderscope is a 6x30 with the G-8 and G-9¼ and a 9x50 with the G-8N and CR-150.

Some of the more useful accessories for these telescopes are the polar alignment scope (for fast polar alignment) and DC motor drives for automatic tracking of celestial objects. Celestron offers a choice of motor drives – a single axis (R.A.) or dual axis. They are powered by four D-cell batteries (not included). Both models include a hand controller with built-in drive corrector for astrophotography.

Computerize your telescope by adding the optional Advanced Astro Master® which is easily installed (use kit #93913 for CG-5 mounts). Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery. Contains an RS-232 serial interface to enable usage with programs like "The Sky" by Software Bisque.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
Visit our Web site at www.celestron.com

CELESTRON® 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835

The Universe Is Full of Mysteries. Using NexStar™ Isn't One of Them.

The joy of stargazing comes from observing the wonders of the heavens, not calculating alignments and positioning. The revolutionary new Celestron NexStar 5 does all that for you and more. Simply and easily.

NexStar 5 is light years ahead of other computerized GOTO telescopes, with Auto Align to get you up and observing immediately and an enormous object data base that includes more than 18,000 celestial sights.

Our Star Pointer Finderscope lets you quickly find any object in the sky, while variable slew speeds provide easy tracking for observation and astrophotography. You can attach our Hand Controller to the telescope's unique fork arm, or hold it for remote operation. There's even a communication port so you can control the NexStar 5 from your computer.

NexStar 5 is designed to go with you anywhere and perform beautifully. The legendary 5" Schmidt-Cassegrain optical system with Starbright® multicoatings guarantee superb views. Best of all, our Tour Function automatically seeks out the most spectacular objects in a given month, while providing you with fascinating facts through the Hand Controller.

If you're looking for a telescope that makes astronomy pure joy and fun, there's no mystery about which one to choose. **Celestron's NexStar 5.**

CELESTRON®

Find out more about NexStar 5, our other exceptional telescopes, and nearby dealers. www.celestron.com

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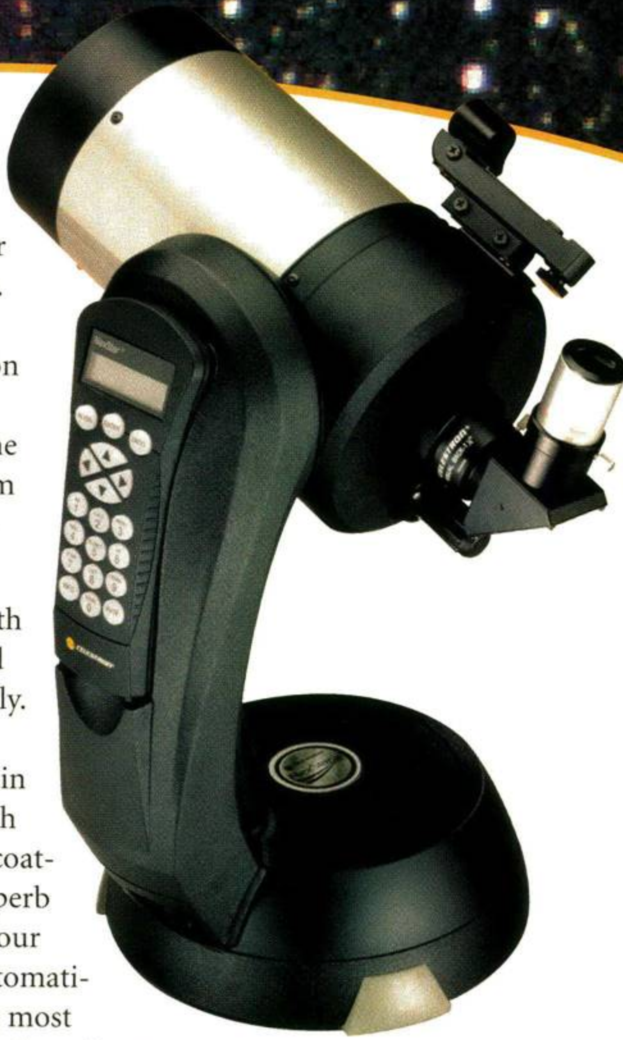

STAR HOPPER® DOBSONIANS

Dobsonian telescopes, by design, combine the strong performance of a Newtonian system, with a simple altazimuth mount. Celestron's Dobsonian design, the Star Hopper® is great for beginners because it's very easy to use and quite economical, yet has advanced features even an experienced observer will appreciate.

STAR HOPPER 4½

- 4½" (114mm) Aperture - 910mm Focal Length, f/8
- Aluminum Optical Tube
- High Quality, Smooth Dob Mount
- Standard 1¼" Accessories: 25mm SMA Eyepiece (36x) and Focuser
- 5x24 Finderscope
- Collimation Tool Standard
- Weight: 18 lbs.

Celestron's Star Hopper 4½ is unique, small Dobsonian telescope that's great for both your own use and for gift-giving. The mount and telescope tube are shipped fully assembled in one box, ready for you to begin observing immediately.

STAR HOPPER

4½"

STAR HOPPER

8"

STAR HOPPER 6 & 8

- 6" (152mm) - 1220mm Focal Length, f/8
- 8" (203mm) - 1220mm Focal Length, f/6
- Precision annealed Pyrex primary mirrors - better than glass used by some competitors, ensure faster temperature stabilization and the highest quality steady optical figure
- Optics are diffraction limited
- Multicoated Primary Mirrors
- Teflon and Nylon surfaces guarantee smooth performing mechanics
- Unique Balance System
- 25mm SMA Wide Angle Eyepiece - 1¼"
- 5x24 Finderscope
- 1¼" Rack and Pinion Focuser
- Collimation Tool - very useful and unique to Celestron
- Made in the U.S.A
- Weight: 6" @ 39 lbs., 8" @ 55 lbs.

6" and 8" Dobs offer one of the best values for an astronomer. Large primary objectives and affordable prices allow first-time astronomers to explore deep-sky objects with ease.

The Dovetail Balance Bar allows for precise balancing of the tube, making the smoothest possible movement. No need to add counterweights!

In summary, *Astronomy Magazine* says, "Star Hopper® is a milestone on the road toward a better commercial Dobsonian telescope. Star Hopper's innovative mirrors, mirror cell and adjustable altitude bearings, combined with its crisp, sharp images more than meet what every Dobsonian owner hopes to have in an easy to use, backyard telescope."

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
Visit our Web site at www.celestron.com

CELESTRON® **2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835**

BRING THE UNIVERSE HOME WITH THE G-3 & G-5

Saturn's rings, galaxies light years away, bees buzzing in a patch of flowers - these images and many, many more can be yours with Celestron's new ultra-portable **G-3** and **G-5** telescopes. These large aperture, multipurpose instruments are full-featured systems ideal for terrestrial viewing, astronomical observing, telephotography as well as astrophotography and they come complete with equatorial mount, tripod, accessory tray and CD-ROM software.

They are the perfect sky-watching tools for amateur astronomers of all levels. Whether you're a first time user or a seasoned cosmic observer, you will appreciate the bright images, sharp contrast and exquisite detail provided by Celestron's legendary U.S.-made optics. Meticulously hand-crafted for optical excellence, the **G-3** and **G-5** are manufactured under strict quality standards.

OPTICS:

- **G-3** - 3½" aperture, 1000mm f/11
- **G-5** - 5" aperture, 1250mm f/10

The **G-3** (Maksutov-Cassegrain optical design) and the **G-5** (Schmidt-Cassegrain optical design) deliver razor sharp images over a wide field. They both feature Celestron's world renowned hand-figured diffraction limited optical systems. Starbright® optical multicoatings provide maximum reflectivity and increased light transmission.

MOUNT AND MOTOR DRIVE

An ultra-durable German equatorial mount is standard on the **G-3** and **G-5**. Setting circles and slow motion controls make it easier to locate and track objects manually. Setup is a breeze with the adjustable height aluminum tripod complete with deluxe accessory tray.

Automatic tracking of celestial objects is yours with the dual speed, single axis motor drive models as pictured above. A hand controller makes observing more fun as objects are easier to center. The built-in drive corrector, which runs on 4 "D" batteries, makes astrophotography possible. Non motor driven models are also available.

STANDARD ACCESSORIES

A 25mm SMA eyepiece - 1¼" (40 power - **G-3**/50 power - **G-5**) is included. The **G-3** includes an 8x20 erect image finderscope and the **G-5** has a 6x30 finderscope.

A fun and educational CD-ROM, "The Sky Level 1 for Celestron," features a 10,000 object database and allows you to print your own custom sky charts.

Test out the new **G-3** and **G-5** at your Celestron dealer today and bring the Universe home.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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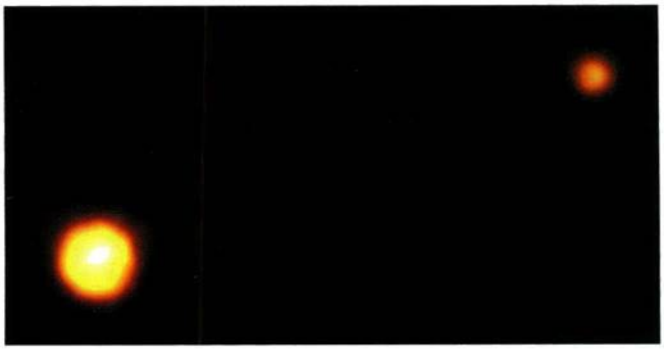
PLANETARY SCIENCE

Pluto Fragments May Be Collision Relics

Like investigators examining highway wreckage to reconstruct an accident, planetary astronomers at the Southwest Research Institute think they have found the rubble produced during an ancient collision. This one involved Pluto and another object. The researchers — S. Alan Stern, Robin Canup, and Daniel Durda — believe a collision gave rise to Charon, Pluto's large moon, as well as to a swarm of icy fragments now orbiting as a "family" in the Kuiper Belt, a frozen realm of comet-like objects orbiting the sun beyond Neptune.

Stern and his colleagues reached their tentative conclusion after they identified a collection of objects with orbits similar to that of Pluto's. The objects also have colors and surface compositions similar to Pluto's. Astronomers have found families of asteroids in the main asteroid belt created by collisions. If the hypothesis of Stern's group is confirmed, Pluto and its "relatives" would compose the first family unit to be discovered in the Kuiper Belt. "It also raises the possibility that some fraction of the short-period comets may be remnants of that collision," says Stern. "Ultimately, we hope to learn about the collision itself by studying the debris."

Bill McKinnon, a planetary scientist at Washington University in St. Louis, Missouri, calls Stern's theory "provocative." However, McKinnon cautions that there's a very large population of bodies unofficially dubbed "Plutinos" — an estimated 10,000 objects bigger than 62 miles (100 km) in diameter with orbits similar to that of Pluto. "The key question is this: Are these also collision fragments or are they debris from the early solar system that was never incorporated into Pluto?" Additional modeling work and spectral observations are needed, McKinnon says, before Pluto's family lineage can be settled. — STEVE NADIS



Pluto, left, and its moon, Charon, right, could have other "relatives" in the Kuiper Belt. R. Albrecht (ESA/ESO) and NASA

NAKED-EYE VISITOR

New Comet Bright in July

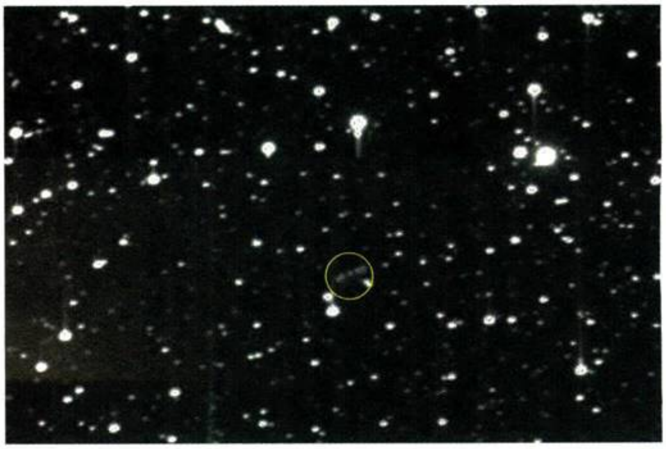
A newly discovered long-period comet may be visible to the naked eye in July, according to the International Astronomical Union's Minor Planet Center (MPC). The comet, called C/1999 S4 (LINEAR) is expected to brighten to 13th magnitude before it passes behind the sun in March. The comet will emerge in May at a predicted 10th magnitude.

The MPC predicts a possible peak brightness greater than magnitude 4 in July, when it will be well placed in the northern sky. However, the MPC's Brian Marsden warns that the comet could be a visual underachiever, especially if it is on its first trip around the sun from its previous address in the Oort Cloud. "I just don't think the comet is intrinsically all that bright," says Marsden.

The comet's closest approach to Earth on July 21 will be at a distance of 0.37 astronomical unit (1 AU is the average sun-Earth distance, about 93 million miles). Perihelion, the comet's closest approach to the sun, will be 0.75 AU on July 24. On that night the comet will be visible from shortly after sunset to shortly before sunrise — provided skies are clear where observations are made.

The comet was discovered September 27, 1999, by the Massachusetts Institute of Technology's Lincoln Laboratory LINEAR (Lincoln Near-Earth Asteroid Research) team operating near Socorro, New Mexico. With this discovery, the LINEAR team tied Lowell Observatory astronomer Carolyn Shoemaker with 32 comets bearing their names as discoverers. Only the Solar and Heliospheric Observatory (SOHO) team has more; 74 comets have been designated with SOHO names. — JOHN FLECK

The new comet "moves" during five exposures taken at 20-minute intervals. Lincoln Laboratory



ACCESSORIES BY CELESTRON

The Celestron Accessories here are universal – use with virtually any telescope.

PLÖSSL EYEPIECES

In a recent *Sky and Telescope* review, Celestron's 1¼" Plössl eyepieces were rated as **top ranking**, and found to outperform many similar, but more expensive eyepieces. An exceptional value! Celestron offers these premium eyepieces at affordable prices, yet they're among the best designed and corrected eyepieces available. They're **multicoated** for enhanced contrast and all models are threaded to accept Celestron colored eyepiece filters. **Focal length with field of view:** 6.3mm (52°), 7.5mm (52°), 10mm (52°), 12.5mm (52°), 17mm (52°), 20mm (52°), 26mm (50°), 32mm (52°), 40mm (46°).

ULTIMA® EYEPIECES

These are Celestron's top of the line 1¼" eyepieces. They feature long eye relief and a wide field, and each air-to-glass surface is **fully multicoated** to enhance contrast levels. These special eyepieces are computer designed to keep visual aberrations to an absolute minimum. Recently, *Sky and Telescope* reviewed Celestron's Ultima® eyepieces and rated them **best in their class**, with greater contrast and image sharpness than the competitive models of other manufacturers. The inside surfaces and edges of all lenses are blackened, to keep out reflected light. Threaded barrels accept Celestron thread-in filters. **Focal length with field of view:** 5mm (50°), 7.5mm (51°), 12.5mm (51°), 18mm (51°), 24mm (51°), 30mm (50°), 35mm (49°), 42mm (36°).

LV EYEPIECES

These Vixen brand 1¼" eyepieces (6 to 8 elements) are a new breed, using the rare earth glass lanthanum in one of their field lenses, for almost total freedom from any visual aberrations. All focal lengths have a comfortable 20mm of eye relief. Even when using the 2.5mm LV eyepiece on a telescope, you'll have eye relief of 20mm! These eyepieces also feature **fully multicoated** lenses for optical excellence. **Focal Length with field of view;** 2.5mm (45°), 4mm (45°), 5mm (45°), 6mm (45°), 9mm (50°), 10mm (50°), 12mm (50°), 15mm (50°), 20mm (50°), 25mm (50°).

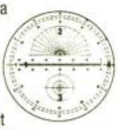
LV ZOOM EYEPIECE

This super premium 1¼" zoom eyepiece has a focal length of 8mm to 24mm. It is the finest zoom eyepiece for low to medium power observing. It's an excellent eyepiece that performs superbly, with **fully multicoated** surfaces. It offers an apparent field of 40° at 24mm and 60° at 8mm. Eye relief ranges from 15mm to 19mm.

CROSS HAIR EYEPIECE

This 1¼" eyepiece is of the Kellner design, with a focal length of 20mm. It's ideal for centering alignment stars when using digital setting circles or computerized telescopes. A useful all-around eyepiece for many applications, including terrestrial observing.

MICRO GUIDE EYEPIECE



This multifunction 1¼" guiding eyepiece features a laser-etched reticle with a built-in battery illuminator. The eyepiece is a **multicoated** 12.5mm Orthoscopic. Usage possibilities include: direct guiding on stars outside the center of the field of view; greatly improved off-axis guiding to capture much fainter, sharply focused guide stars without reducing limiting magnitude; and measuring position angles and separation of double stars. **Its finely etched micrometer scale** has gradations 50 microns apart and 15 microns wide. Included are: the eyepiece, built-in cordless illuminator with adjustable brightness control, batteries and instructions.

BARLOW LENSES

Celestron's premium quality .96" and 1¼" achromatic Barlow lenses are compact and lightweight. Both are under three inches long, with the 1¼" lens weighing in at 4 ounces and the .96" lens a mere 2 ounces! The clear aperture is 27mm on the 1¼" model, and 21mm on the .96" unit. The .96" Barlow is **fully multicoated** and the 1¼" lens is **multicoated.** The Ultima® Series Barlow (2x – 1¼") is an air-spaced, three element apochromatic design with a 27mm clear aperture. This lens features a very high quality, **fully multicoated** design. Amazingly compact and lightweight, it's just 5 ounces and 2¾" in length.

DIAGONALS

Celestron's Erect Image Diagonals are an Amici prism design. This design allows you to look into the telescope at a 45° angle, at images that are oriented properly, meaning the image is upright and correct from left to right. .96" to 1¼" models are available. Use of Celestron's hybrid .96" to 1¼" 45° Erect Image Diagonal on a telescope equipped with .96" eyepieces means greater versatility. This diagonal will allow you to use 1¼" eyepieces to obtain a larger field of view and better eye relief. A 90° 1¼" Erect Image Diagonal is available for those who prefer that angle. A 1¼" Star Diagonal (90°) is also available.

EYEPIECE FILTERS

Eyepiece filters are an invaluable aid in lunar and planetary observing. They reduce glare and light scattering, increase contrast through selective filtration, increase definition and resolution, reduce irradiation and lessen eye fatigue. Celestron's filters are made of high quality, solid plane parallel glass with excellent homogeneity. They're **antireflection coated** to prevent glaring and ghosting. All eyepiece filters are threaded to fit Celestron's, and most other manufacturer's, 1¼" eyepieces, and offer a full 26mm clear aperture. Filters available individually are: #12 Deep Yellow, #21 Orange, #25 Red, #58 Green, #80A Light Blue, #96 – 25% T, #96 – 13% T, Polarizing. In addition four different sets of four filters each are available.

1¼" POLARIZING FILTER SET

It's particularly useful for reducing glare while observing the moon, double stars, the planets and terrestrial subjects. You can vary the degree of transmission. By causing the amount of transmitted light to vary, the filters become, in effect, a continuously variable neutral density filter.

LPR FILTERS

Light Pollution Reduction (LPR) Filters are designed to selectively reduce the transmission of certain wavelengths of light, specifically those produced by artificial light. As a result, Celestron LPR Filters darken the background sky, making deep-sky observation of nebulae, star clusters and galaxies possible from urban areas. While blocking unwanted light, Celestron LPR Filters permit the transmission of more desirable wavelengths. This will improve your viewing of emission nebulae, both from urban and rural settings. They're also protected with a **broadband antireflection coating** to prevent ghosting and to improve contrast. They provide superior performance and contrast over competitive models. A 1¼" model threads into 1¼" eyepieces to work with virtually all telescopes.

MOON FILTERS

Celestron's Moon Filter threads into 1¼" eyepieces and aids in reducing the brightness of the moon and improving contrast, so greater detail can be observed on the lunar surface. The clear aperture is 21mm.

VIBRATION SUPPRESSION PADS

Telescope vibration is caused by windy conditions, an unsteady mount or tripod or even an accidental bump to the instrument, and results in reduced image quality. Celestron's set of three Vibration Suppression Pads **will reduce vibration time by almost 100%** and decrease vibration amplitude. The pads fit between the bottom of the tripod legs and the ground, a simple and functional solution to the problem of image disturbance.

NIGHT VISION FLASHLIGHT

Celestron's premium model for astronomy uses **two red LEDs** to preserve night vision better than red filters or other devices. Brightness is adjustable. Operates on a single 9 volt battery (included).

LENSPEN™

A superb new tool in optical lens cleaning technology. Perfect for cleaning binocular lenses, small aperture spotting scopes and telescopes, eyepieces, and other optical items. The LensPen™ comes with a handy retractable dust removal brush and a special non-liquid cleaning element, designed to never dry out. Safe and very easy to use.

SKY MAPS

Celestron Sky Maps are the ideal teaching guide for learning the night sky. You wouldn't set off on a road trip without a road map, and you don't need to try to navigate the night sky without a map either. Even if you already know your way around the major constellations, these maps can help you locate all kinds of fascinating objects. The front cover has a specially designed **luminous planisphere** that rotates to simulate the seasonal progression of celestial objects through the sky. When the planisphere is pre-exposed to light, star positions glow brightly against a dark background, mimicking actual constellations. More than a thousand stars and deep-sky objects are listed and charted.

PLANISPHERE

A simple and inexpensive tool for all levels of observers, from naked eye viewers to users of highly sophisticated telescopes. The Celestron Planisphere makes it easy to locate stars for observing and is a great planet finder as well. The Celestron Planisphere comes in three different models, to match the latitude from which you're observing: 20° to 40°, 30° to 50°, 40° to 60°.

TELESCOPE EQUATORIAL MOUNT–CG-3

A durable, rigid, German equatorial mount with a wooden tripod, offering both affordability and high quality. Designed as an excellent and inexpensive upgrade option when you're ready to move to a sturdier mount for your beginning telescope. R.A. and DEC setting circles, a latitude scale, slow motion controls and a handy accessory tray are included.

TELESCOPE EQUATORIAL MOUNT–CG-4

The CG-4 mount is a very rigid German equatorial mount. A counterweight, latitude scale, setting circles and slow motion controls on both axes are standard. The adjustable height aluminum, rigid tripod has **excellent damping characteristics** and a handy accessory tray. It is the same mount as used on Celestron HD telescopes and is a step up from the CG-3. Optional motor drives and a polar alignment finderscope are available.

TELESCOPE EQUATORIAL MOUNT–CG-5

The CG-5 EQ mount is the newest generation of Celestron's German mounts. Both axes of the equatorial mount have **precision worm gears** for extremely smooth motion. It is a step up from the CG-4. This **heavy-duty mount** delivers jitter-free images easily and the adjustable height aluminum, rigid tripod has excellent damping characteristics and a convenient accessory tray. Included are setting circles on both axes, slow-motion controls and latitude scale. An adjustable counterweight makes it easy to point, balance and use. An optional polar alignment scope for fast polar alignment as well as motor drives are available for easy tracking.

ALT-AZ PHOTO TRIPOD MOUNT

This heavy-duty mount is perfect for cameras with large telephoto lenses, and for spotting scopes and binoculars. If you already own a small telescope mount and are interested in one offering greater stability, the Alt-Az is an ideal upgrade. The adjustable wood tripod comes with two slow motion cables and is equipped with a ¼" x 20 photo head.

For more detailed information on these and other Celestron Accessories, contact a Celestron dealer or Celestron. Visit our Web site at www.celestron.com

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DIAMOND SHOWERS

Neptune and Uranus Are Gems

▶ Neptune is a planetary gem whose hydrocarbon-rich middle layer rains diamond crystals, and the same could be true of Uranus, according to a report in *Science*. "It's very different from what we thought was happening inside those planets," says Laura Robin Benedetti of the University of California at Berkeley, a coauthor of the report.

The surprising conclusions are based on laboratory experiments by Benedetti and UC Berkeley colleague Raymond Jeanloz. They compressed a pinhead's worth of methane inside a laser-heated diamond anvil to replicate the two gas-giant planets' atmospheric pressures, which are hundreds of thousands of times greater than Earth's. Under extreme conditions, methane (each molecule contains one carbon atom and four hydrogen atoms) splits to form diamond dust (100 percent carbon) and hydrocarbon leftovers.

"It's an eye-opening confirmation of a theory that scientists scarcely dared talk about in public because it's so far out," says John S. Lewis, a planetary scientist at the University of Arizona in Tucson. "But the solar system is far out."

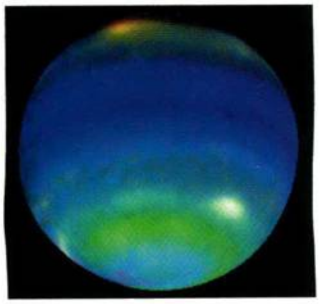
Benedetti and Jeanloz caution that the methane chemistry is complicated by the presence of ammonia and water, but diamond formation still would occur. Even without a spacecraft to descend into the planet, astronomers might use a technique called planetary seismology to search for a diamond core. Similar diamond production is not expected on Jupiter and Saturn because their atmospheres have little methane, a necessary source of the carbon in diamonds.

Diamond production might help explain the excess energy — beyond that from reflected sunlight — radiating from Neptune: The falling diamonds, perhaps the size of pebbles, encountering resistance in the liquid interior would give off heat.

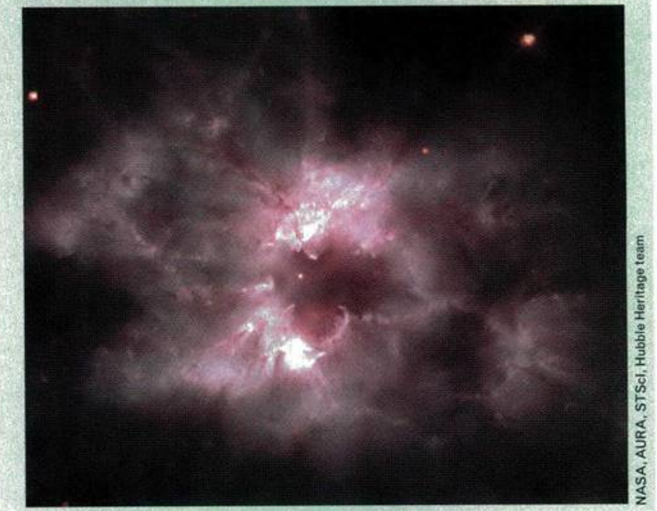
The experiment also may answer the debate over whether the planets have solid cores. If the California scientists are right, the planets have a heart of diamond — and it could be hundreds of miles thick.

— David Graham

Neptune's methane-rich atmosphere may be forging diamonds. STScI, NASA



STELLAR DEATH SHROUD



NASA, AURA, STScI, Hubble Heritage team

ONE OF THE HOTTEST STARS KNOWN lies in a shroud of gas 4,000 light-years from Earth in the direction of the constellation Puppis. The dying star radiates with a temperature of about 360,000° F (200,000° C) and is surrounded by a pinkish planetary nebula (known as NGC 2440). The star's intense ultraviolet radiation causes the surrounding gas to fluoresce in visible light. The optically glowing ionized gas is surrounded by a larger cloud of cooler molecular gas that can be detected only in the infrared region of the spectrum. The structure of NGC 2440 suggests an episodic and chaotic outflow from the central star. This image is one of four released on the first anniversary of the Hubble Heritage Project, an effort by the Space Telescope Science Institute in Baltimore, Maryland, to bridge the gap between astronomers and the public through artistically compelling photographs taken by the Hubble Space Telescope.

CRAB NEBULA

Chandra Scope Reveals Mysterious Ring

▶ Only months into its expected 5- to 10-year lifetime, NASA's Chandra X-ray Observatory is paying astronomical dividends. One of Chandra's early images reveals a never-before-seen x-ray-emitting ring around the pulsar at the heart of the Crab Nebula (M1), a supernova remnant about 6,000 light-years away in Taurus. This image may help explain how the city-sized pulsar illuminates and powers the nebula, which is 10 light-years across.

Spinning 30 times per second, the pulsar, which formed during the supernova that created the Crab Nebula, generates a magnetic field that is millions of times more powerful than Earth's. It also accelerates subatomic particles — electrons and positrons — to nearly the speed of light. Somehow, this energy of 100,000 suns illuminates the entire nebula from within. The nebula itself consists mostly of ejecta from the exploded star.

Chandra was able to see the light-year-wide ring because the space telescope's angular resolution is

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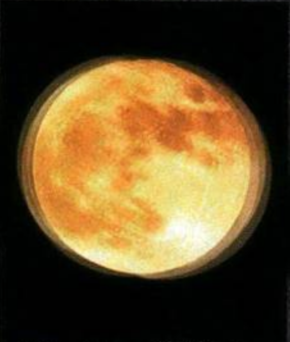

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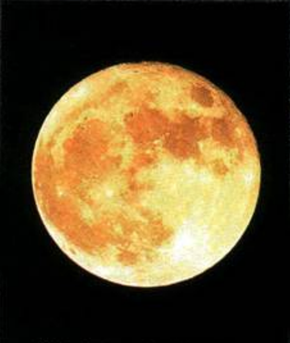

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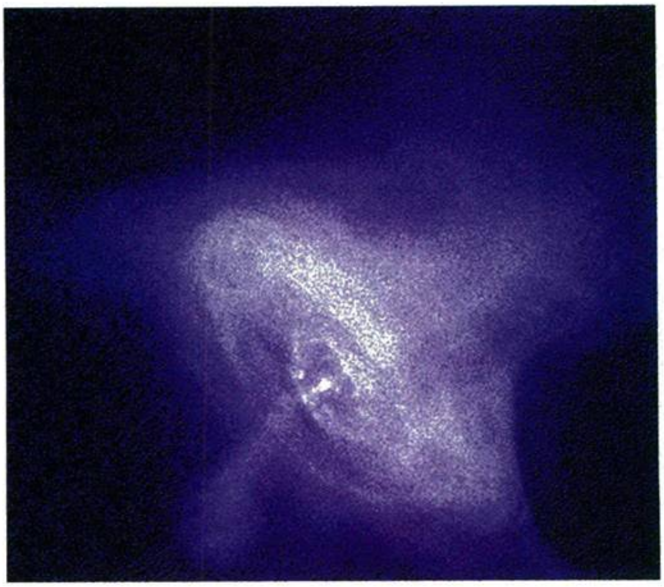
10 times sharper than any other x-ray observatory. "It seems as though we are finally seeing the glowing power conduit that connects the Crab pulsar and the nebula," says Arizona State University astronomer Jeff Hester. "The ring is exactly in the place that it needs to be in order to be the thing that ties the pulsar to the larger nebula."

Hester emphasizes that more observations are needed to understand how the pulsar transfers energy to the nebula.

Chandra might also be clearing up another mystery surrounding supernova remnants. According to models of how stars evolve, when a massive star goes supernova, it leaves behind a neutron star. However, many supernova remnants show no evidence of neutron stars. One of Chandra's first images revealed a pointlike x-ray source near the center of the Cassiopeia A supernova remnant (see "Chandra First Light," November 1999). The point source is probably the long-sought neutron star that formed at the same time as Cassiopeia A.

A new Chandra image of the supernova remnant G21.5–0.9, which is 16,000 light-years away in the constellation Scutum, also reveals a pointlike x-ray source near the center of the nebula, where no neutron star had previously been seen. More research is needed to prove that the Cassiopeia A and G21.5–0.9 point sources are neutron stars. But Chandra X-ray Observatory Center science director Harvey Tananbaum says, "If that turns out to be correct, it's incredibly important scientifically."

— Robert Naeye



The Crab Nebula has a ring surrounding its central pulsar, and high-speed jets shoot out from the highly energetic pulsar in opposite directions.

NASA, Chandra X-ray Observatory Center

FASTER, CHEAPER

NASA Scrambling To Surmount Orbiter Loss

▶ NASA's "faster, better, cheaper" philosophy increasingly defines the space agency's feverish attempts to recover scientifically and politically in the wake of the abrupt failure of the $125-million Mars Climate Orbiter (MCO). Prior to its 1998 launch, key flight data were not converted from English to metric units, as required. The glitch went undetected until the robotic spacecraft flew too low into the martian atmosphere on September 23 and presumably overheated.

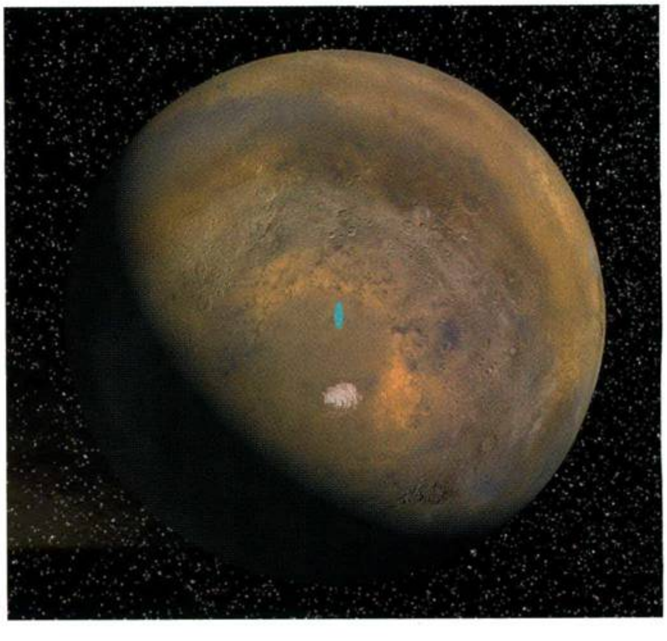
Another Mars mission, NASA's Mars Polar Lander (MPL), is scheduled to touch down December 3 near the planet's south pole. Mission planners had intended to use MCO during the Polar Lander's three-month lifetime to relay data from the Lander to Earth. Now what?

Carl Pilcher, NASA's science director for solar system exploration, insists that MPL can transmit data to Earth without a relay. "By compressing the data somewhat more than originally planned, the full science return of the MPL mission can be achieved," he says.

Michael Malin, president and chief scientist of Malin Space Science Systems, agrees that the solar-powered MPL should meet its science objectives despite the loss of Climate Orbiter. (Malin Space Science Systems, a company based in San Diego, California, built the cameras for the Mars Climate Orbiter and the ill-fated Mars Observer and helped NASA recover from that 1993 loss by developing the camera for the Mars Global Surveyor.)

The Polar Lander's antenna will permit it to communicate directly with Earth, although at a slower rate than would have been possible with a communications relay. "There is also a capability to use the Mars Global Surveyor to relay data back to Earth, but the use of that relay has yet to be fully investigated," says

The Mars Polar Lander target is marked in blue. NASA, JPL



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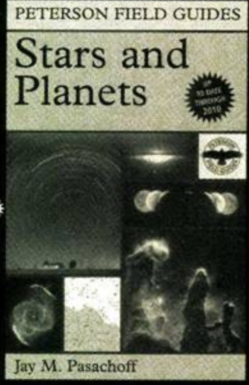

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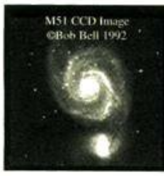

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Malin. He thinks that recovering all the MCO's science goals will be very difficult. However, NASA is investigating ways of adding a wide-angle meteorology camera to the Mars Surveyor 2001 mission.

Scientists also are considering various ways of making up for the Climate Orbiter loss, such as adding instruments that went down with Orbiter to other Mars missions set for launch several years from now. Those instruments would measure atmospheric temperatures, pressures, and occasionally composition as a function of height above the ground. "The (MCO) mission will certainly not be duplicated in the near future," says Malin. "Future missions may recover some, or even most, of the objectives, but the enormous scientific advantage of flying the strongly complementary and synergistic climate payload will be lost unless NASA attempts another climate mission."

The Climate Orbiter failure didn't surprise some researchers. Peter Smith of the Lunar and Planetary Laboratory at the University of Arizona in Tucson says that NASA's faster, better, cheaper approach to spaceflight overworks scientists to the point where human mistakes become more likely. The approach was pioneered by NASA Administrator Dan Goldin.

"Indeed, there have been more losses of spacecraft in recent years at NASA than in the decade or two prior to the Goldin philosophy," notes Paul Murdin of the United Kingdom's Particle Physics and Astronomy Research Council. "But I hasten to add that there have been many more spacecraft launched." — Paul Parsons

ASTROPHYSICS

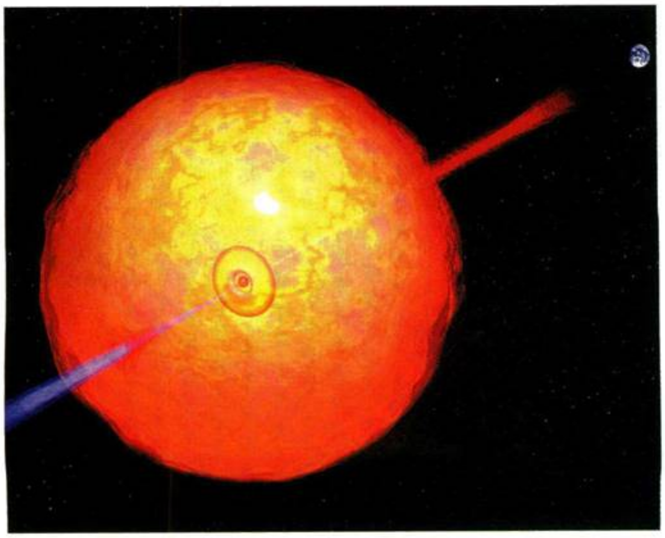
Gamma-Ray Burst May Have Spawned a Supernova

▶ Gamma-ray bursts (GRBs) — brief, intense discharges of radiation believed to be the most energetic phenomena in the universe — have mystified astronomers for three decades. A violent merger of two neutron stars could theoretically trigger a GRB, but new evidence shows that a sudden collapse of a massive star likely produced a recent GRB. Evidence comes by way of a concurrent observation of an apparent supernova.

Joshua Bloom and his colleagues at the California Institute of Technology in Pasadena, California, reported in *Nature* that they discovered the characteristic red light emitted by a supernova. The light reached a maximum 30 days after the GRB of March 26, 1998. Excited by the Caltech analysis, astronomers at the University of Amsterdam and at the University of Chicago reported the detection of a similar supernova afterglow. Their supernova was at the position of the GRB of February 28, 1997 — the first gamma-ray burst for which an optical counterpart was discovered.

In a model that explains the phenomenon, a spinning black hole forms, which both destroys the star (leading to a supernova) and produces jets of particles traveling near the speed of light, which give rise to the gamma-ray burst. "This appears to be the smoking gun for the origin of some gamma-ray bursts," says Bloom. "A perfect marriage of the two brightest events in the universe."

— Alexander Hellemans



In seconds, the iron core of a massive star implodes and a black hole is formed. Energetic jets moving at nearly the speed of light produce a burst of gamma rays that plow through the star, causing it to explode. If one of the jets is pointing directly toward Earth, astronomers can detect a burst of gamma rays in addition to a supernova explosion. Artist's conception by Jonathan Williams (Caltech)

DEEP INSIGHT

Supernova Clues Found in Antarctic Ice

▶ In early 1999, shortly after discovering a 700-year-old supernova remnant hiding in the southeast corner of the well-known Vela supernova remnant, Max-Planck Institute astronomer Bernd Aschenbach began to hunt for evidence of the explosion. Little did he know that remnant RX J0582.0–4622 had left behind fingerprints deep in the Antarctic ice.

This story of scientific sleuthing began in 1979. That was when a team of scientists discovered four instances of enhanced abundances, or "spikes," of nitrate — a molecule of one nitrogen atom and three oxygen atoms — in ice deposits at the South Pole. Scientists can identify past events in layers of polar ice, in the same way that geologists and biologists obtain clues about the history of Earth in its sediment layers.

Interestingly, three of the enhanced-nitrate spikes occurred in 1181, 1572, and 1604 — years when the most recent, nearby supernovae seen from Earth exploded. The discovery sparked a debate: Did high-energy radiation from these supernovae collide with atoms in our atmosphere and shower Earth with nitrates? If so, how can one explain the mysterious fourth nitrate spike in 1320? And why did Greenland ice contain no evidence of the nitrate spikes?

It would be two decades before the next clue would come to light. It arrived as a

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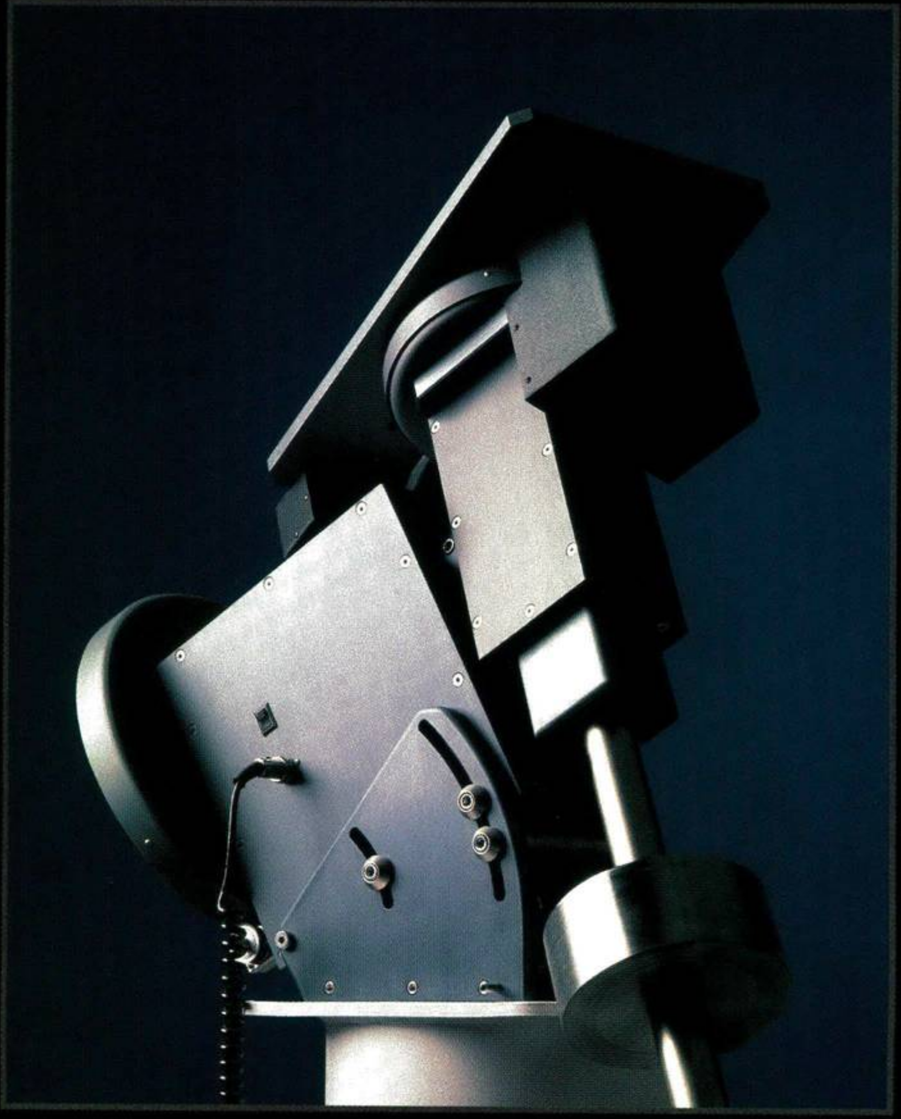

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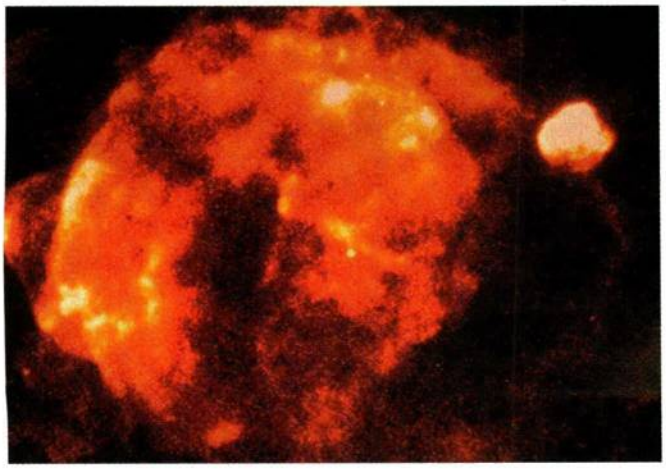
ROSAT image of a supernova remnant almost obscured by the older background Vela remnant. "A year ago, (coworker) Kai Zuber and I noticed the ROSAT article by Aschenbach," says McGill University physicist Clifford Burgess, "and we realized it could explain the fourth spike." Burgess and Zuber reported the insight in an Internet journal operated by Los Alamos National Laboratory.

"The age is surprisingly close to our early estimate," agrees Aschenbach, adding that the fourth spike gives a "more precise date that is valuable to concentrate the efforts searching for eyewitness data."

The absence of spikes in Greenland ice cores puzzles Burgess, but a simple test will convince him that supernovae produce the South Pole spikes. "There are records of two other nearby supernovae in 1006 and 1054," notes Burgess, "someone should go to the South Pole, dig deeper, and find the two spikes." — Mark W. Sincell



ROSAT showed the x-ray emissions of the 11,000-year-old Vela supernova remnant, as well as a younger, background supernova remnant (upper right).

ROSAT, MPE, NASA

UNUSUAL RING

Undiscovered Moons May Shape Neptunian Ring

▶ The similarities between the many rings around Saturn might suggest that all planetary rings should be broad, flat, and relatively featureless. However, the most distant of Neptune's rings breaks the mold.

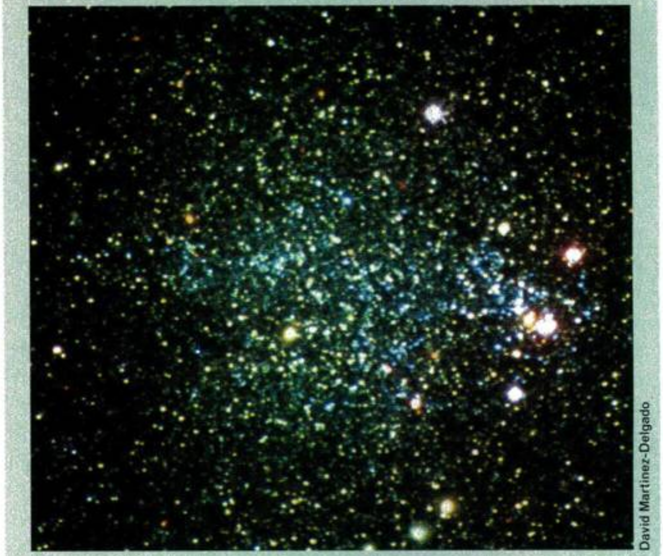
Astronomers have known for 15 years that the Adams Ring contains "ring arcs" that remain intact while circling Neptune every 10.5 hours. "Without any mechanisms to confine them, we would expect the arcs to spread out in a matter of a few months, but they don't spread," says Christophe Dumas, an astronomer at the Jet Propulsion Laboratory in Pasadena, California. "There is something going on there."

In a paper published in *Nature*, Dumas and four coauthors reported that an analysis of Hubble Space Telescope images ruled out the widely accepted theory. That theory proposed that the longevity of the ring arcs is due to "co-rotation resonance" with the neptunian moon Galatea.

The moon orbits the planet at the inner edge of the Adams Ring on a path that is slightly inclined in relation to the ring. An accompanying paper in *Nature* reported the same conclusion based on observations by astronomers using the Canada-France-Hawaii Telescope in Hawaii. "Galatea is responsible for perturbations in the ring arcs," says Dumas, "but it can't explain, by itself, the confinement of the ring material."

Instead, the most recent observations support a theory that one or more "shepherding" satellites only a few miles in diameter orbit within the Adams Ring. The satellites would confine the four ring arcs called Courage, Liberté, Egalité, and Fraternité. The as-yet-unseen moons are thought to keep the icy

THE LOCAL GROUP



David Martinez-Delgado

THE PHOENIX DWARF GALAXY lies about 1.3 million light-years away in our Local Group of galaxies. The Phoenix dwarf is dominated by red stars and blue stars in the central region surrounded by a sphere of older stars. The finding, reported by David Martinez-Delgado and collaborators of the Instituto de Astrofísica de Canarias in *The Astronomical Journal,* confirms recent star formation in the inner part of this galaxy. Finding such youthful (100-million-year-old) stars is surprising because dwarf galaxies are thought by many cosmologists to have assembled billions of years ago, before the epoch of giant-galaxy formation. The Phoenix dwarf's young stars, observed with the 100-inch du Pont Telescope at Las Campanas Observatory in Chile, are distributed asymmetrically in the galaxy's central region, indicating that a recent wave of star formation swept that region.

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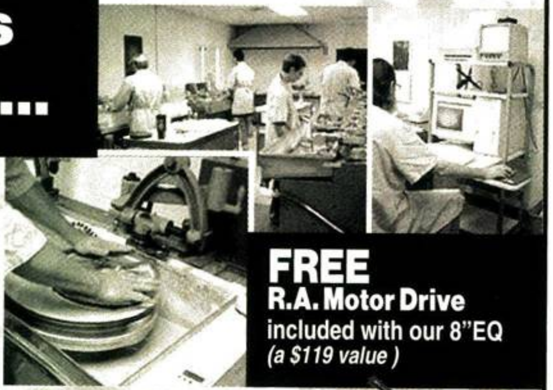

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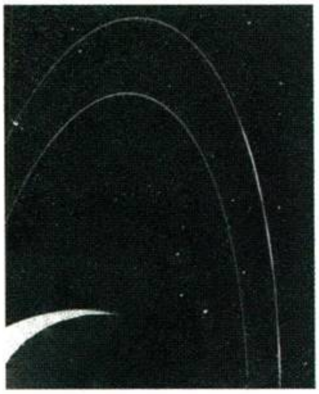

This 1989 Voyager image shows three ring arcs, known as Liberté, Egalité, and Fraternité, in Neptune's outer ring. The fainter ring arc Courage was discovered later. NASA, JPL

dust in the arcs from spreading and dissipating along the length of the ring. "The next stage will be to go back to the Voyager 2 data from 1989 and see if we missed something at the time — small moonlets inside the Adams Ring," says Dumas. He said further observations of the distribution of material within the ring arcs — to be carried out with large ground-based telescopes such as the Keck Telescopes in Hawaii — may provide important clues about the unseen objects that confine them.

— Rex Graham

SHORELINE THEORY

Mars Craters Lost at Sea?

▶ Impact craters in North America and Scandinavia could help measure the depth of ancient oceans on Mars. The martian oceans are long gone, of course, but that's just the point, says Jens Ormo of the Universita d'Annunzio in Pescara, Italy.

The oceans that covered some impact craters on Earth are also long gone, yet the craters have features that betray their marine origins. The same features are also found in martian craters, suggesting they, too, were made while those locations were underwater.

One giveaway is radial gullies, which are formed by seawater blown away by the impact that surges back into the crater. These gullies and other telltale features, such as the absence of a rim, tend to appear if the water in an ancient sea was about as deep as the crater was large, says Ormo. If the water was shallower, the crater would look more like one that was created on land. So comparing craters in close proximity that are roughly of equal age but different sizes could give away the amount of water that once was there.

Ormo presented his results at the October 1999 conference of the Division for Planetary Sciences of the American Astronomical Society in Padua, Italy. He has compared his sample of craters on Earth with impact craters on Mars located near the escarpment between the northern plains and the southern highlands. That feature, according to some researchers, represents an old shoreline.

According to Ormo, the impact craters just on the high side of the martian escarpment show the signature of shallow-sea craters, lending support to the shoreline theory.

But there's a catch. A recent analysis of high-resolution Mars Global Surveyor images of suspected ancient martian shorelines found no evidence of such ancient shorelines.

— Bas den Hond

Ocean Tides May Crack Europa's Surface Ice

Dark, wedge-shaped bands may begin as cycloidal cracks.

Gregory V. Hoppa, et al.

Planetary scientists at the University of Arizona in Tucson have developed a computer model that explains the formation of bizarre "cycloidal" fissures on Jupiter's moon Europa. The lengthy cracks form, according to the model, when Europa's solid-ice surface rises and falls with the tides in Europa's subsurface ocean. For more, go to www.astronomy.com/horizon.html.

An X-ray Source Nibbles Familiar Star

A well-known variable star — GM Sgr in the constellation Sagittarius — apparently is acting up, feeding material to a massive, compact companion that seems to show its appreciation with a brilliant x-ray belch. While observing the center of the Milky Way Galaxy, a team using the BeppoSAX x-ray astronomy satellite observed a transient x-ray outburst that was coincident with GM Sgr. The object became almost one-tenth as bright as the Crab pulsar and then faded away. A neutron star or black hole is most likely orbiting GM Sgr and causing all the fuss. For more, go to www.astronomy.com/horizon.html.

Teacher Linked with Stolen Antique Telescope Lens

The lens of this Clark telescope has been recovered.

Terry Hubbert

Federal authorities have found an 8.25-inch lens made in 1880 by Alvan Clark & Sons, which was taken in 1981 from a telescope on display in the Cincinnati Astronomical Society's remote observatory. A federal grand jury recently indicted Robert Keith Thomas, a soft-spoken, 50-year-old community college adjunct professor, for possessing the stolen lens from 1981 to 1997. Thomas also was charged with making false statements to the FBI. The teacher at Roane State Community College in Harriman, Tennessee, donated the lens in 1997 to be used in the school's new Tamke-Allan Observatory and Environmental Center. For more, go to www.astronomy.com/horizon.html.

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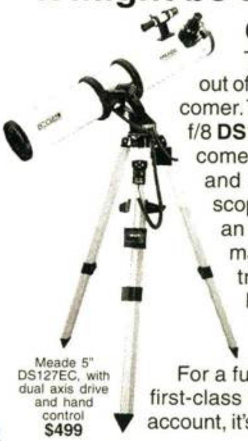

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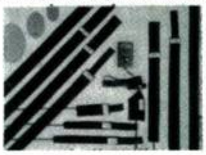

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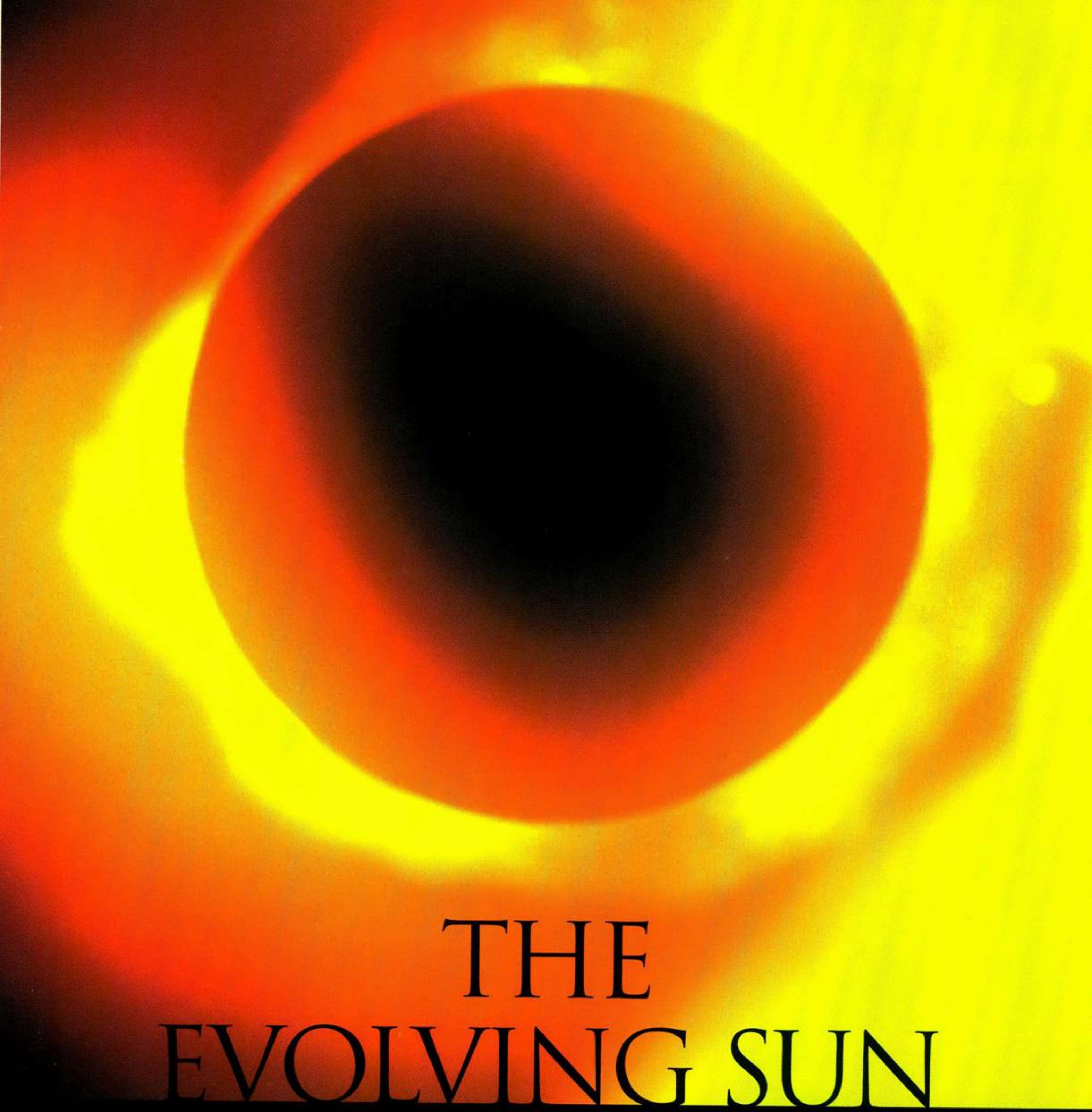
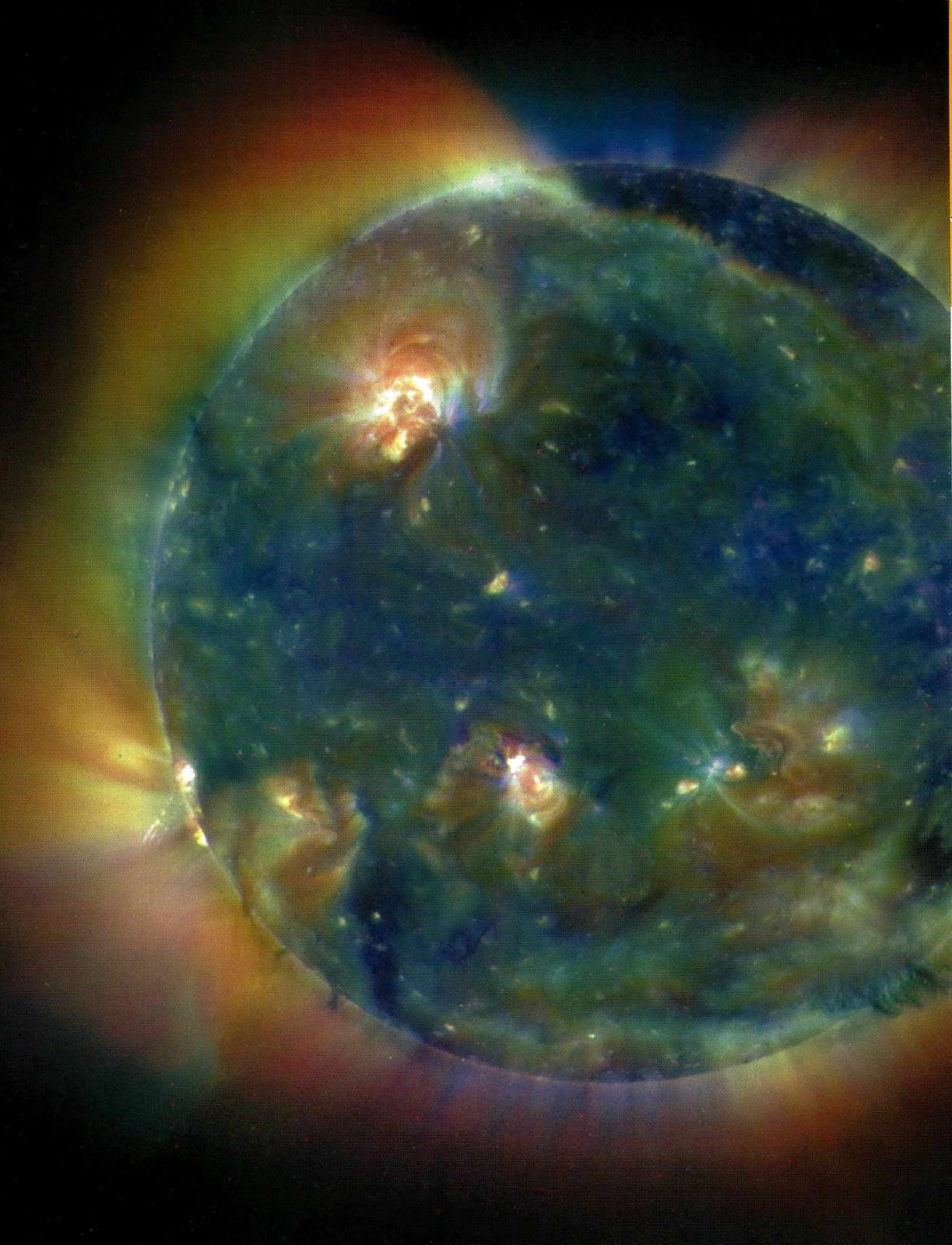
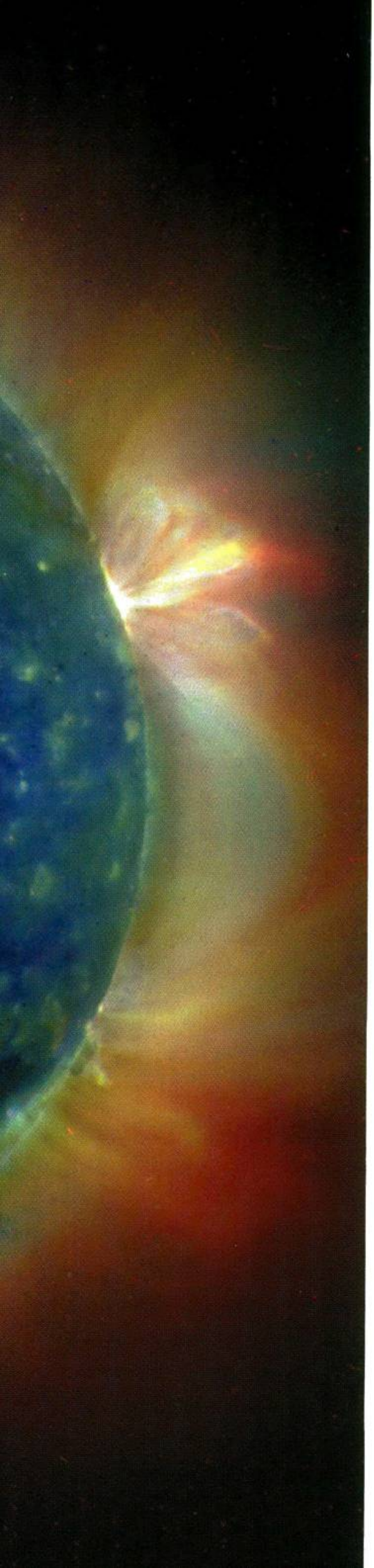


THE EVOLVING SUN

It is the preeminent ruler of each day, the seasons, the blue sky. The sun's sway over the human psyche is equivalent to its pull on the planets. However, the sun is getting hotter as it ages, and its benevolent reign will end sooner than many might suspect. The following five stories will profile the sun, several scientists who study it, and our need to eventually leave our planet in search of another. Photo Illustration by Steve Puetzer





CURTAIN CALL

We've got one billion years
— maybe much less than that —
before the sun transforms Earth into a parched purgatory.

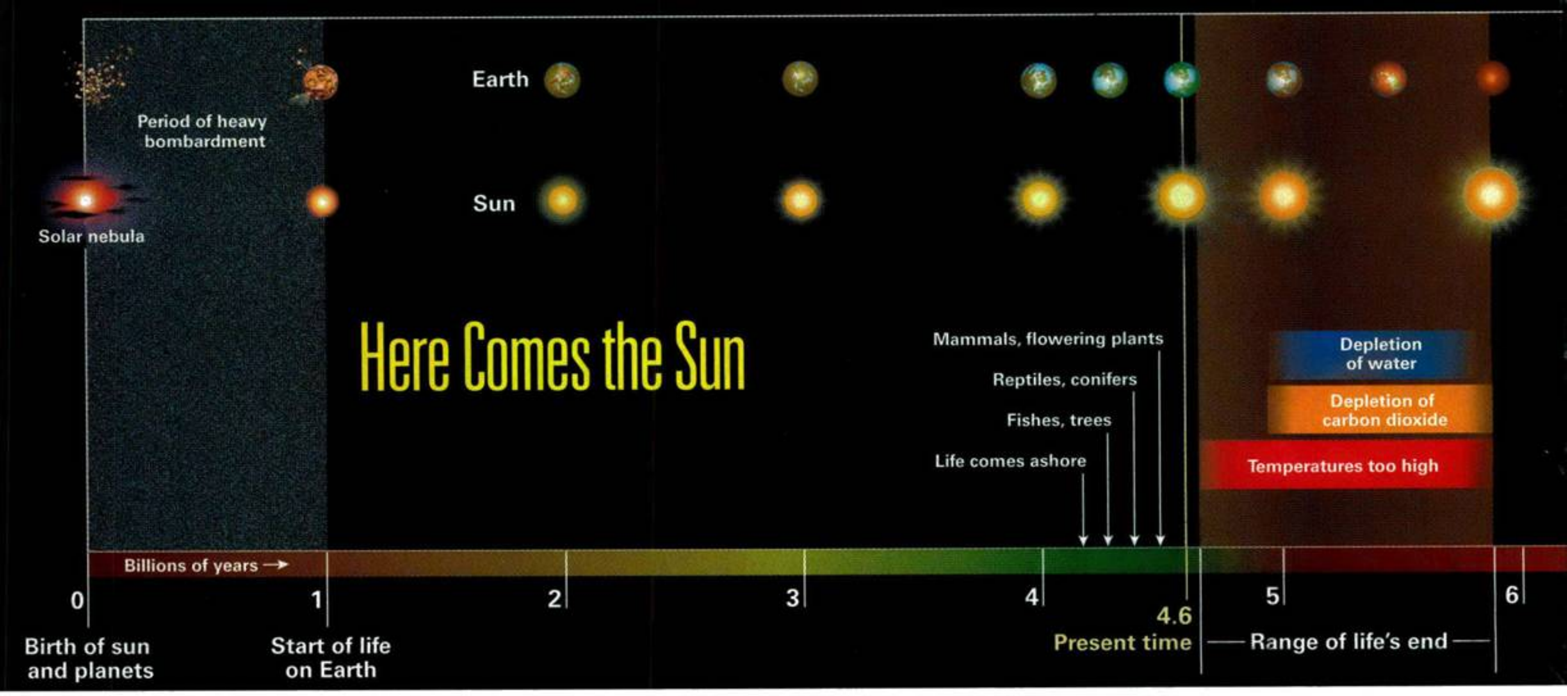
by Thomas Hayden

ETERNITY IS A RELATIVE TERM. WE'VE KNOWN FOR A GENERATION THAT our time on Earth will come to a predictable, cataclysmic end when the sun eventually exhausts its hydrogen supply and swells outward as a monstrous, planet-engulfing red giant. But the hydrogen is expected to last at least another 5 billion years. Our compatibility with the sun has seemed to extend essentially forever. For a society congratulating itself on having survived Y2K, a specific but distant end in Y5G or thereabouts is definitely Not Our Problem. Still, every time astrophysicists probe the workings of the sun, climatologists seem to revise the lifespan of our habitable Earth downward. Too many uncertainties remain to nail down a definite date for the helio-apocalypse, but it is becoming clear that our 4.6-billion-year dance with a benign sun will conclude sooner than we might have thought.

We'll still be cutting turns around the planetary ballroom for a while — 1 billion years? 500 million? 200 million? — but the swansong will play long before the sun runs out of hydrogen. Maybe it's still not our problem, but by the time the music stops let's hope that someone has mastered interstellar flight, because Earth will become hotter and hotter, eventually roasting whatever clings to its surface as the oceans boil away and carbon dioxide depletes. The end result will be an Earth that will look similar to an uncratered Mercury with baked, exposed floors of former oceans.

For now, solar physicists describe the sun's life phase as boring. Ever since the solar nebula spun down into the infant sun and internal temperatures and density built up to the point where hydrogen began fusing into helium — about 27 million° F (15 million° C) at a density 160 times that of water on Earth — it's been on the hydrogen-burning, or main-sequence, stage. This stage lasts for 11 billion years of the sun's predicted 12-billion-year lifespan. Finally, it will pass through initial and secondary red giant phases and end life as a slowly expanding planetary nebula surrounding a blazingly hot white dwarf, a tiny remnant star stripped of its outer atmosphere. The sun's life has lasted 4.6 billion years so far. In terms of luminosity, temperature, and size, our star is about as stable as it will ever

This solar image taken in May 1998 reveals the sun's high-temperature corona (blue shows 1.8 million° F, green 2.7 million, and red 3.6 million). NASA, SOHO, EIT Consortium


Here Comes the Sun

be. Still, models suggest that the sun's output will increase slowly and steadily until its hydrogen fuel runs dry. Solar luminosity will jump 10 percent over the next 1.1 billion years. The sun's surface will grow 1 percent hotter over that period, from 9940° F (5500° C) to 10,050° F (5560° C).

To astrophysicists who routinely deal with bursts of energy too gargantuan to comprehend, such minor changes barely register. But to climatologists, a 10-percent increase in solar output is an astounding quantity.

"Right now we're worrying about tenths of a percent," says Judith Lean of the Naval Research Laboratory in Washington, D.C. "To be climatically significant, one-quarter of a percent may be enough." She studies changes in luminosity associated with the 11-year sunspot cycle and their effects on climate. The terrestrial impacts of even short-lived spikes in solar output may foreshadow much bigger effects as the sun's luminosity slowly rises. It's also possible that sunspot activity will increase.

"At that level of outer surface activity, neither theory nor observation is sufficient to be much of a guide," says astrophysicist John Bahcall of the Institute for Advanced Study in Princeton, New Jersey, "but sunspots don't affect overall evolution." No, but variations in the sun's cycles on top of the steady increase in luminosity could ripple through Earth's atmosphere in some profoundly unpleasant ways.

THE SOLAR FURNACE

It all starts in the sun's core, hundreds of thousands of miles below the teeming, surging outer layers. This is the nuclear furnace, the 27 million° F kiln where slightly more than 600 million tons of hydrogen are fused into helium every second, converting the equivalent of 4.3 million tons of matter into pure energy (mostly heat and light) according to Einstein's equation $E = mc^2$.

The simple reaction, whereby four hydrogen nuclei fuse to form an atom of helium, produces the sun's radiant energy. The reaction has some serious energetic hurdles to overcome — on average, it takes hydrogen nuclei several billion years to overcome mutual repulsion — so the reaction proceeds like a nicely regulated reactor rather than a bomb. As hydrogen fuses into helium, the mass remains almost unchanged, but the number of particles in the core decreases: The core contracts and gets hotter until the increasing pressure balances the weight of the upper layers. This increase in density and temperature also increases the nuclear-reaction rate, which makes the sun brighten. The increasing luminosity flowing through the sun's upper layers causes them to slowly expand.

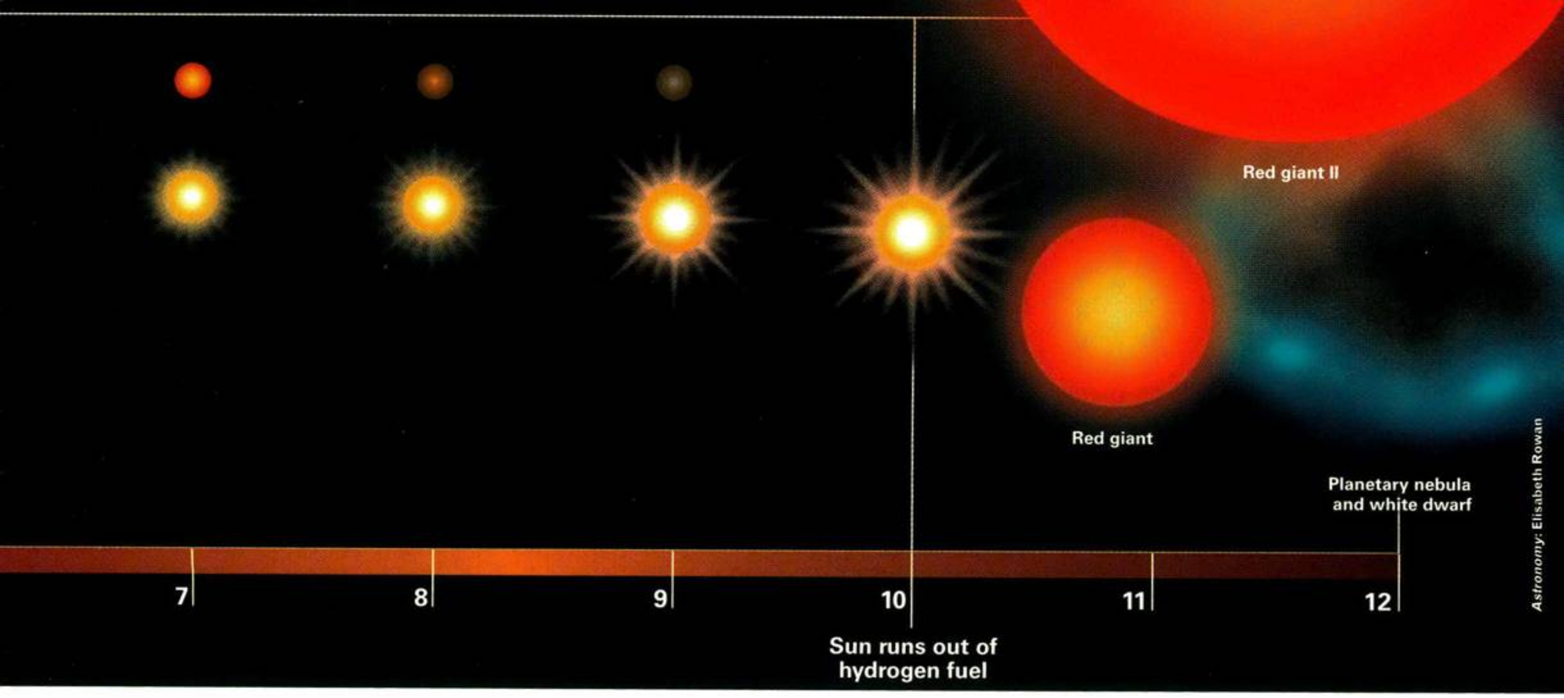
"Solar luminosity over the next billion years will grow steadily," says Arnold Boothroyd, who studies stellar evolution at the California Institute of Technology in Pasadena, California. "It's almost linear for the next several billion years." Energy released in the core radiates outward. Photons are absorbed and re-emitted so many times along the way that they typically take a million years to reach the surface. From there it's just 93 million miles and 8 minutes of relative freedom until the photons slam into the outer edge of Earth's atmosphere. In some ways, that's just the beginning of the trip.

OUR SECURITY BLANKET

Earth's atmosphere acts as security blanket, suit of armor, and source of raw materials all in one. Solar photons shoot through the gases of the upper atmosphere like innumerable steel balls caroming down the board of a pinball machine. Almost a third are bounced back into space. The rest are absorbed in the atmosphere or into the surface, adding warmth, setting up the temperature gradients that drive winds and storms, powering photosynthesis, and, if you're not careful, causing sunburns.

Solar radiation raises our planet's temperature by 450° F (250° C), to 0° F (–18° C). Greenhouse gases in the atmosphere — carbon dioxide, water vapor, and methane, for example — raise it further, to a more life-friendly average of about 60° F (15° C) by absorbing infrared radiation that would otherwise be lost back into space.

Anyone questioning whether small changes in solar output can significantly impact Earth's climate would do well to check historical records from the mid-16th through the 17th centuries. For as yet unknown reasons, the sunspot cycle essentially shut down during that period. Astronomers call it the Maunder minimum. Historians refer to the period as the Little Ice Age, the coldest period of time since the last great ice age 10,000 years ago. Glaciers in Norway and Switzerland expanded down mountain valleys, overrunning farms. The Thames River in England froze for the first time in history.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Sun runs out of hydrogen fuel

Astronomy: Elisabeth Rowan

Danish astronomer Tycho Brahe recorded winter temperatures that were 2.7° F (1.5° C) below average during the last two decades of the 16th century. Europe's population stalled, crops failed, and grain prices escalated. Sea ice cut Iceland off from the mainland. Why? "It's speculative," says Lean, because there is no historical record chronicling solar radiation. Fortunately, changes in the sun's activity are recorded in such proxies as the amount of radioactive carbon-14 in tree rings. Lean and other scientists have used such data to deduce that solar radiation decreased by a quarter of a percent during that period.

If a decrease of 0.25 percent in solar output can cause such drastic effects on our climate, what would an equivalent increase do? According to climate simulations conducted by Lean and David Rind of the Goddard Institute for Space Studies in New York, the news is not good. "When you increase total solar radiation by 0.25 percent, the model says you get a nine-tenths of a degree Farenheit or half a degree Celsius increase in surface temperature," says Lean. But divining exactly how climate would respond is tricky — that's why there's a global-warming debate.

"Temperature changes over time are not linear," says Rind, a climate modeler. The nonlinearity is caused by various feedback mechanisms that set the planet's temperature. As Earth warms, for example, sea ice melts. That means more sunlight is absorbed, and the atmosphere warms even more. But that effect only lasts until the sea ice is gone — at some point greater than a 4-percent increase in solar radiation.

WATER VAPOR'S ROLE

Less well understood is the role of water vapor, a powerful greenhouse gas. "As temperature increases, the concentration of water in the air increases exponentially," says Rind. "There's a possibility of runaway greenhouse warming."

The sun's sunspot pattern could have a profound effect. Sunspots are composed of darkened, cooler regions — the spots themselves — and the surrounding faculae, areas that are brighter and hotter. "Younger stars are dominated more by the spots," says Lean. "In our sun, faculae dominate. We expect that as the sun evolves faculae will become even more dominant."

Because faculae emit an order of magnitude more UV radiation than visible-light radiation, a facula-dominated sun is a stronger UV source. And UV creates ozone in the stratosphere. That ozone, in turn, can either increase or decrease the rate of warming depending on whether it forms in the upper or lower stratosphere.

The further away from present conditions, the harder it is to predict how climate will respond. When Rind runs his model with a 2-percent increase in solar radiation, the global temperature increases about 7° F (4° C). Climatologists don't usually think a billion years out, so Rind hasn't run that simulation, but he speculates that "a ten-percent increase in the solar luminosity would probably give you in the ball park of twenty-one degrees Farenheit or twelve degrees Celsius warming." And the results of that? "Pretty catastrophic." A 3.6° F (2° C) increase in global temperature is expected to cause the sea level to rise by 15.6 inches (40 cm), due to melting ice. Even a 12-inch (30-cm) rise in the sea level would inundate an estimated 3,000 square miles of Louisiana's biologically rich coastline and wetlands, one-third of Florida's Everglades, and fresh-water sources for major coastal cities. A 2-foot rise would swamp an estimated 10,000 square miles of U.S. coastal land.

"Twenty-one degrees [F] would be beyond the pale." says Rind. We're talking melting polar ice caps, severely disrupted climate, more frequent and more violent storms, general misery, and mayhem. Still, we'll probably have advanced enough to make it through those coming changes more or less in stride, or at least without going extinct. But hot weather, it turns out, is going to be the least of our problems.

FAILING FEEDBACK MECHANISMS

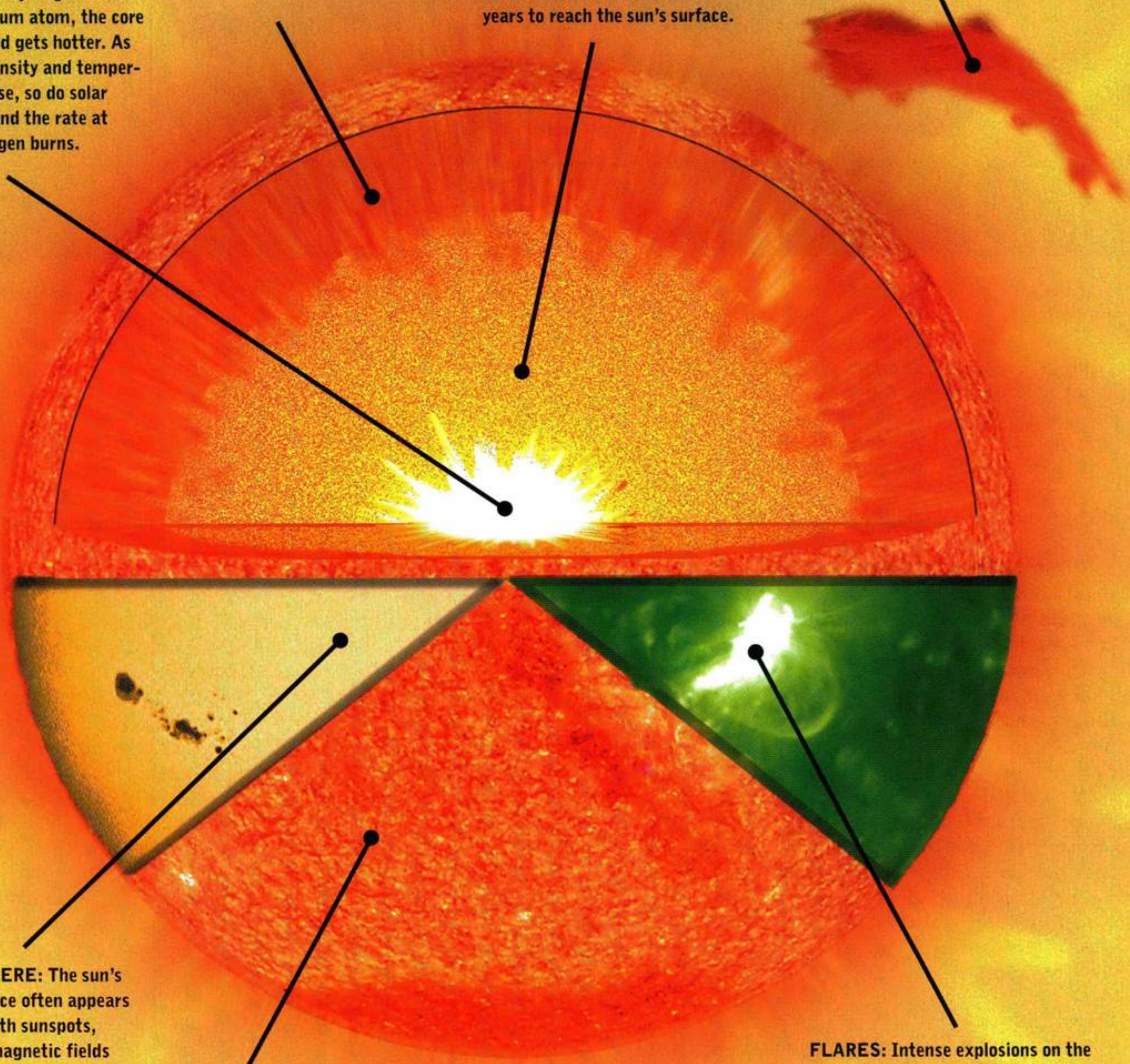
Earth's climatic system contains a beautifully balanced thermostat and is no stranger to major changes in solar output. As the sun has become 30 percent more luminous over the past 4.6 billion years, the feedback mechanisms have provided Earth with liquid water. Ironically, one of the most powerful control mechanisms may eventually do us in. Cloud cover and ice sheets can be effective regulators in the short term, but the main thermostat lies in the relationship between atmospheric carbon dioxide and global surface temperatures. Most of the carbon in the world is locked up as carbonate in rocks. Warmer temperatures mean increased rates of evaporation, rainfall, and stronger winds, all of which contribute to erosion. "So if it's warmer, you get faster weathering of silicate rocks,"

CONVECTIVE ZONE: The interior of the sun is 27 million° F (15 million° C), while the surface is only a few thousand degrees. Temperature gradients induce strong convection currents that produce granulation structures and other inhomogeneities on the sun's surface.

RADIATIVE ZONE: Photons move less than 0.4 inch (1 cm) before interacting with surrounding matter and subsequently scattering in random directions. For that reason, each photon takes between 1 and 2 million years to reach the sun's surface.

PROMINENCE: These dense clouds of material suspended by loops of magnetic field often remain in a quiet state for days or weeks. However, as the magnetic loops that support them slowly change, filaments and prominences erupt and rise from the sun over the course of minutes or hours.

CORE: In the reaction that converts four hydrogen atoms into one helium atom, the core contracts and gets hotter. As the core's density and temperature increase, so do solar luminosity and the rate at which hydrogen burns.

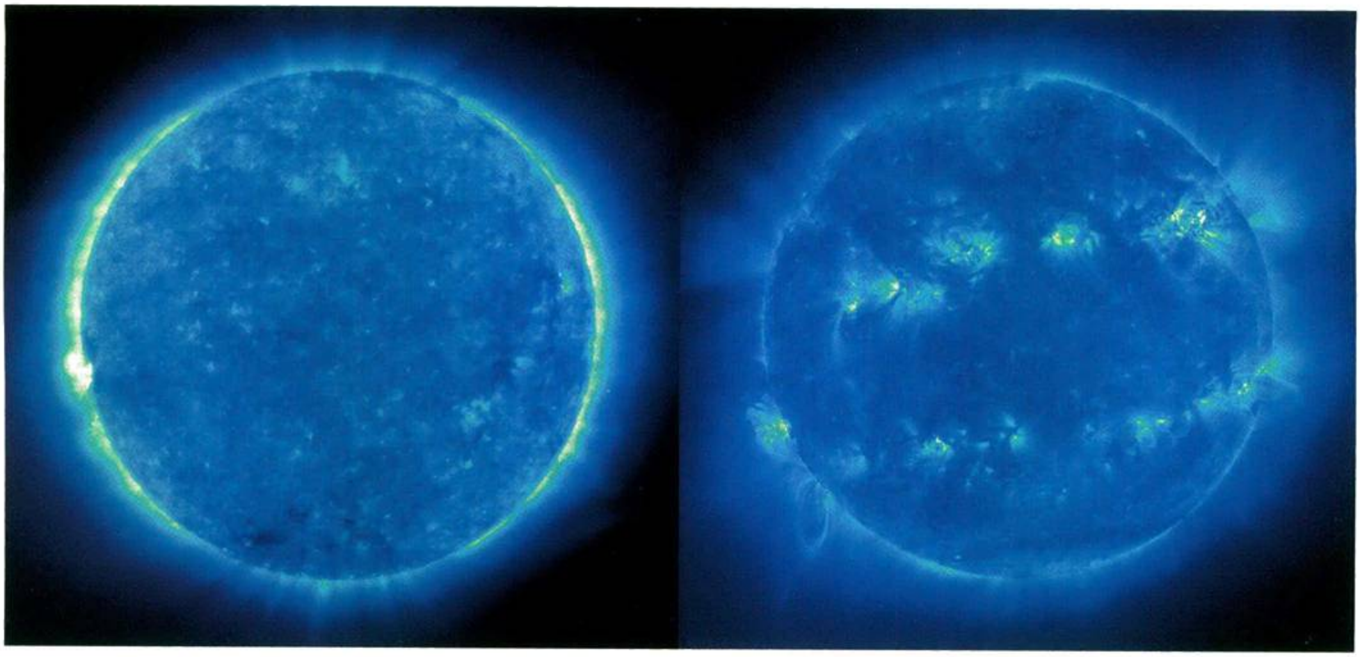


PHOTOSPHERE: The sun's visible surface often appears peppered with sunspots, centers of magnetic fields thousands of miles wide that sometimes persist for weeks or months.

CHROMOSPHERE: The atmosphere above the photosphere looks like a thin colored band around the sun during a total eclipse. Many scientists believe that pressure waves propagating upward from the photosphere heat the chromosphere from about 7200° F at its base to as high as about 17,000° F.

CORONA: The outermost region of the sun's atmosphere containing diffuse gases reaches several million degrees Fahrenheit, attains supersonic speeds, and contains structures such as streamers, plumes, and loops that conform to magnetic-field lines. The corona is visible during total solar eclipses as a pearly-white crown surrounding the sun.

FLARES: Intense explosions on the sun's surface known as solar flares heat solar gases to millions of degrees in only a few minutes, and each one releases as much energy as a billion megatons of TNT. Flares occur near sunspots between magnetic fields of opposite polarity.



Solar activity increased sharply from early 1997 (left) to late 1998 (right). The lines trace 1.8-million-degree coronal gas. NASA, SOHO, EIT Consortium

says James Kasting, a geoscientist at Pennsylvania State University. That kicks off a series of reactions: calcium eroded from the silicate rocks makes its way into the oceans, where it combines with carbonate to make shells and corals and so on, which sink to the seafloor. The ocean's carbonate supply is replenished by carbon dioxide from the atmosphere. Carbon dioxide that was once in the air ends up at the bottom of the ocean as carbonate rock.

The process has helped keep global warming under control through the sun's evolution so far, says Kasting. "This is the process that some people think has stabilized temperature over the last four billion years." But there are limits even to this powerful regulator.

In climate-model simulations, says Kasting, who studies the physical factors that define the "habitable zone" around stars, "the levels got down to about one hundred forty parts per million (ppm) carbon dioxide in about five hundred million years." And most plants, termed C3 plants after the type of photosynthesis they use, require about 150 ppm to photosynthesize. "C3 plants make up about ninety-five percent of what's out there," says Kasting, including most of Earth's substantial array of food crops.

Five hundred million years is a long time, long enough for the C4 plants, which require less carbon dioxide, to replace the vanishing C3s, and long enough for plants to evolve new carbon-dioxide-harvesting mechanisms. But once initiated, the carbon-dioxide loss rolls along relentlessly. "By 900 million years, the C4 plants start having problems," says Kasting. No carbon, no plants, no us.

APOCALYPSE

It's hard to imagine surviving those crises. Maybe we will ranch the sulfur-based ecosystems of deep-ocean vents. Tube-worm and giant-clam brochette, anyone? But that's just a prelude to full planetary extinction. "In about 1.1 billion years the stratosphere gets wet," says Kasting. That hardly sounds ominous, unless you know a little photochemistry. "The water," he says, "is dissociated by UV light, and the liberated hydrogen is lost forever." The oceans evaporate and all remaining forms of life are extinguished.

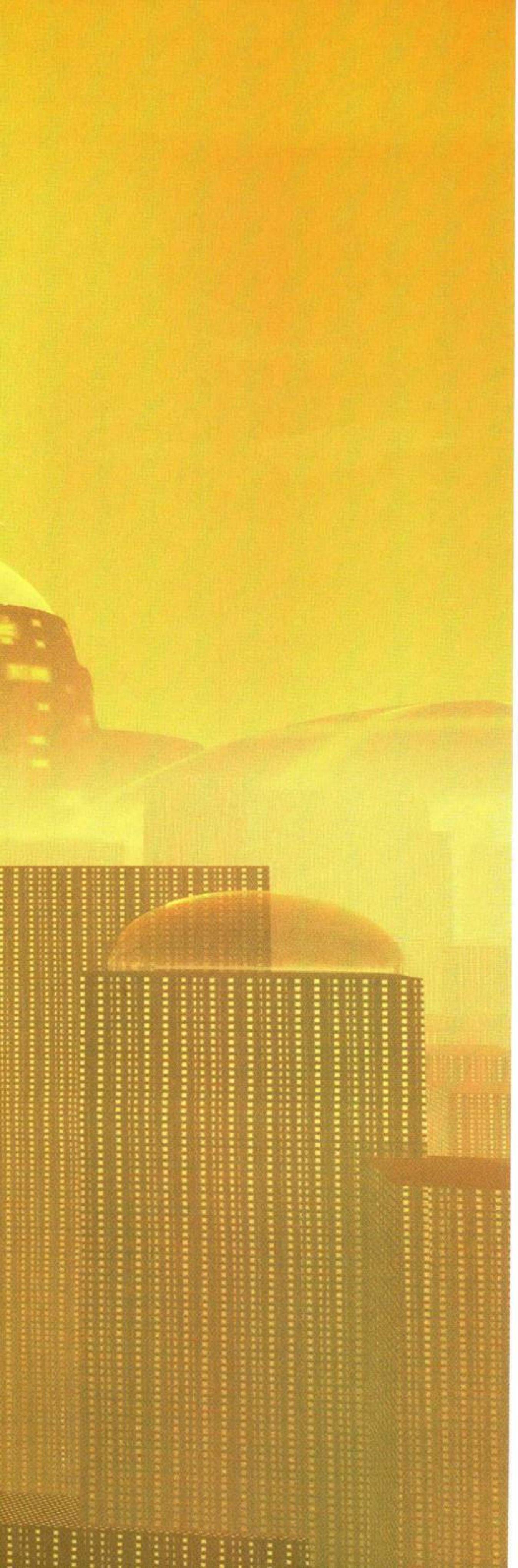
So in just over a billion years, long before the sun exhausts its supply of hydrogen, the show will come to a harsh end. Kasting's simulations ignore the effects of increasing cloud cover with hotter temperature, which are notoriously difficult to model. "Cloud feedbacks will probably slow the rate of warming," he says, "so our scenario is the most pessimistic." At best, clouds offer temporary relief — there's only so much sky to be filled before that feedback mechanism is saturated. Whether in 300 or 800 million years, life on Earth will be scarce. Microbes may flourish longer underground.

What of the planet we leave behind? "It's frustrating that we won't be around to see how it turns out," says Lean. It's also a bit of a relief. Until recently astronomers believed the sun would lose so much mass on its way to becoming a white dwarf that Earth's orbit would expand enough to avoid being obliterated by the growing sun. Lee Anne Willson, an astrophysicist at Iowa State University in Ames, has spent 25 years working out the details of the final stages of solar evolution, as the sun transforms from a red giant into the dormant white-dwarf stage. "It turns out that the fate of Earth is very sensitive to how that process goes," she says.

It all depends on how much mass the sun loses, and at which point during its evolution that happens. If mass is lost early on, the dry, sterile Earth of the future could escape being vaporized by its dying star as the planet's orbit would expand in response to the sun's lower mass. That would let Earth orbit somewhere near Mars's current position as a silent memorial to the life that once coated its surface. If the mass loss occurs late in the process, however, Earth would be scorched to a cinder and possibly pulled into the growing sun's fiery maw. Willson, who's finishing her calculations, will reveal the ending at a February conference on the sun's future, but she says, "Earth probably doesn't get away."

Thomas Hayden, a former oceanographer, was a AAAS Mass Media fellow in 1997. He now covers science for Newsweek.

Steele Hill, Raytheon ITSS/NASA



EXODUS from EARTH

As the sun desiccates this planet, we will seek our destiny in the stars.

Text by Tom Siegfried
Illustrations by Walter Myers

In Isaac Asimov's famous Foundation *novels, humans populated most of the Milky Way Galaxy. Only dim memories remained of the home planet, which had been rendered uninhabitable in the distant past by a robot.*

Like all the robots in Asimov's fiction, this one was programmed to protect and serve humankind. Irradiating Earth was the robot's way of encouraging exploration — of getting lazy earthlings to fulfill their manifest destiny on a galactic scale.

In reality, Earth won't need a robot. The sun itself one day will force the issue. In half a billion years, more or less, rising solar heat will transform global warming into planetary purgatory. Earth will be simply too hot to sustain human life. Our descendants will be forced to depart the home planet, seeking asylum on worlds now unknown.

Nowadays, such a mass departure is unthinkable. We don't know where to go or how to get there. Even a small spaceship of colonists, say a modern day Mayflower, *would most likely turn into an interstellar* Titanic.

Of course, half a billion years in the future seems too far away to begin worrying already. But when it comes to interstellar migration, a good rule of thumb is never put off till Armageddon what you can contemplate today. Given the obstacles involved and the human proclivity to procrastinate, it may take millions of years to solve the problems that will arise when the time to go draws closer.

In half a billion years, more or less, the sun will scorch Earth and probably force its intelligent inhabitants to become interstellar trekkers.

A LONG GOOD-BYE

A successful migration will require earthlings to confront and resolve serious issues of science, technology, and ethics. Science, perhaps surprisingly, should be the least of those problems. The next 500 million years will bring a deeper understanding of the cosmos, beyond the comprehension of today's brightest minds. But even without unexpected scientific advances, we already know that science can make interstellar travel possible. True, Einstein's theory of special relativity poses a strict speed limit for interstellar flight, namely the speed of light. That could mean interstellar migration will proceed much more slowly than the settlement of the American West. Even with luck and lots of planets to choose from, at feasible sublight speeds the nearest destinations would be at least decades away. However, time would slow for those traveling at near-light speeds, so they might not experience the trip as taking so long.

Long trips may require creative travel arrangements, perhaps the old science-fiction standby of suspended animation. Or possibly the biological science of the future will provide a compact form of special delivery, maybe DNA cubes that can grow themselves into people upon arrival. Impatient humans may want to get to the next world faster by exceeding the speed of light, even though Einstein proved it impossible. It's a reflection of the way space and time are woven together. But space and time are strange enough that scientists can see loopholes in relativity's limits. What Einstein's special relativity theory takes away, his general relativity theory gives back — maybe — with a little help from quantum physics.

General relativity contains within its equations clues for transportation at superluminal "warp" speeds. In 1994, Miguel Alcubierre of the University of Wales in Cardiff proposed that a bubble of spacetime (and passengers within) could be manipulated to flow across the universe faster than light does. It's simply a matter of making the spacetime in front of the bubble contract while the spacetime behind it expands. Maintaining such a "warp bubble" would require a dose of negative energy — unthinkable to Newtonian minds but possibly available to future travelers through the magic of quantum mechanics. Alcubierre's concept has been criticized, naturally, and the scientific jury remains out on whether his idea will fly in reality.

But a more recent analysis by Chris Van Den Broeck of Katholieke Universiteit Leuven in Belgium finds that many of the problems posed by the critics can be evaded. "Even so," he says, "it is clear that warp drive presents enormous practical difficulties that may never be overcome." If the warp bubble idea bursts, science might offer a selection of alternate routes to long-distance relocation.

Given enough time, the quirks of quantum mechanics and relativity may offer now-unknown ways of reshaping space, enabling some sort of spacecraft to take us from here to there, however far away "there" might be.

A SPEEDY ESCAPE

In fact, the idea of "far away" may not survive the coming millennia. Already physicists suspect that current notions of space and time are primitive. They probably conceal secret dimensions, almost surely of space, and perhaps even of time.

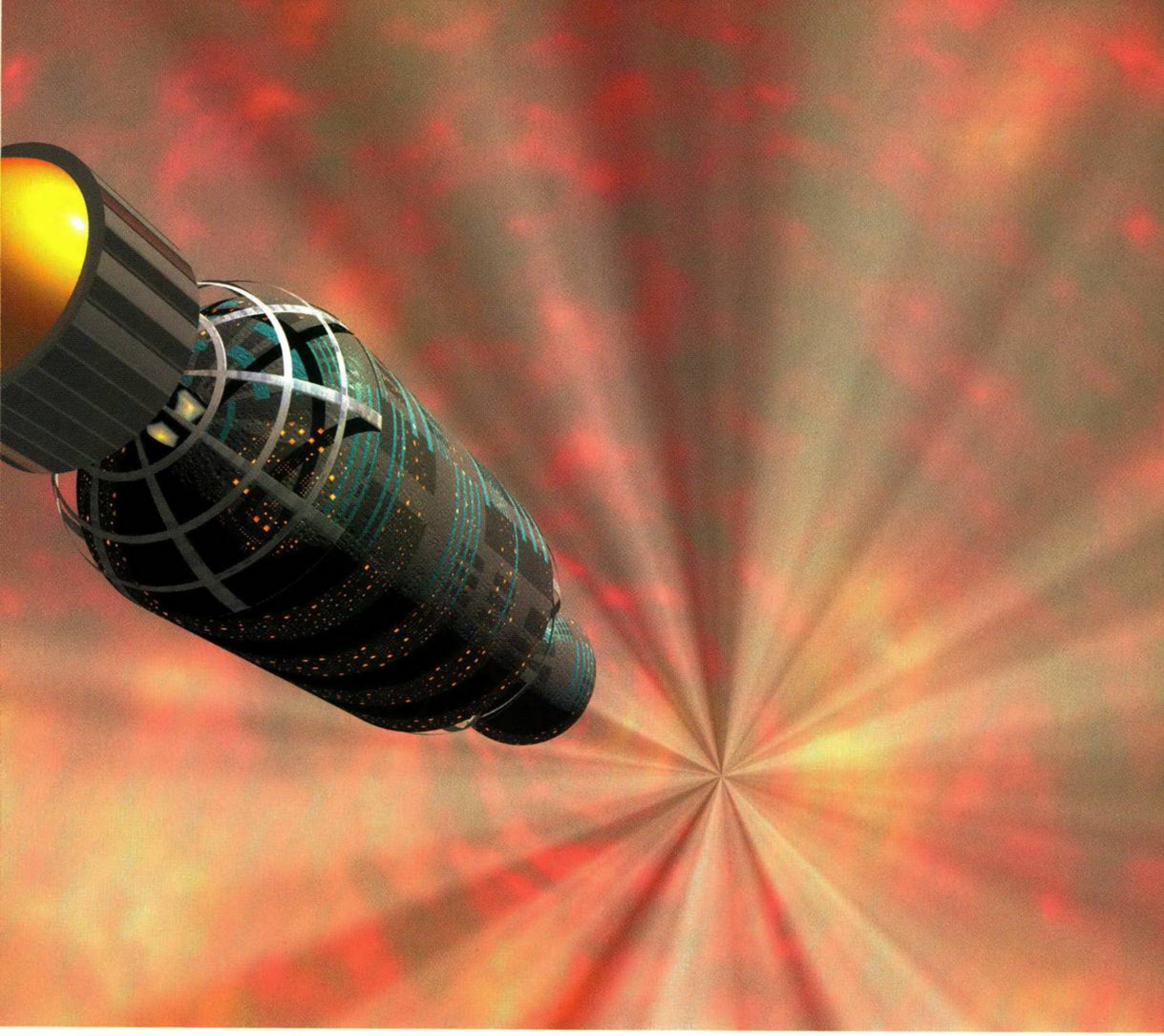
It may be that travel through extra dimensions will forever be impossible, but understanding them might cast the problem in a new, more solvable form. After all, time is still rather poorly understood. Deeper insight into time's flow and direction could suggest novel forms of rapid transit, along the lines of the wormholes in Carl Sagan's *Contact*. Perhaps the key to conquering space will be conquering the mystery of time.

Given whatever method of travel science provides, humankind's descendants will still have to decide where to go and anticipate what they'll find when they get there. At the moment, the prospects for finding a destination look more favorable than they used to. A decade ago, it wasn't so clear that future travelers through the sea of space would ever find planetary surfaces suitable for habitation. Since 1995, though, astronomers have detected more than 20 planets orbiting stars in the galactic neighborhood. All of them are gas giants the size of Jupiter or larger with no solid surface to walk upon, probably no oxygen to breathe, and frequently as hot as a blast furnace. Yet their relative abundance suggests that planets, including habitable ones, are plentiful.

Whether homey planets like Earth with the right amalgam of air, water, and weather will be easy to find is another issue. Extrasolar planets detected so far are more like Jupiter, and most are too close to their own star to colonize. It remains to be seen whether some smaller and more temperate terrestrial worlds occupy our corner of the Galaxy.

Today's scientists aren't sure why Earth is habitable. Reviewing the planet-search prospects in the *Proceedings of the National Academy of Sciences*, planetary scientist Jonathan Lunine of the Lunar and Planetary Laboratory at the University of Arizona points out

Interstellar travel may require us to perfect suspended animation as well as novel spacecraft propulsion technology.



that determining the "habitability zone" for orbits around a star is not a straightforward task. Presumably, a habitable planet must have a solid surface and an orbit that allows the presence of liquid water. "Yet even the stability of liquid water on Earth over its geologic history is not well understood," notes Lunine. A planet around a sunlike star, roughly the same distance from it as Earth is from the sun, may well not offer the amenities that we would require.

"The general requirements for habitability are very poorly understood," Lunine observes. "The story of Earth's habitability is surprisingly complex." It may be that a complicated set of physical features plus, perhaps, some lucky accidents in the past, made Earth into a space oasis. Similar planets around other stars may not have been as lucky.

Nevertheless, given sufficient time and technology, the sky searchers of the future will more than likely find a new home for humankind. But once humans identify such a place and devise the technology to take them there, the problems really begin. For as skillful as our species has been at science and technology, we sometimes seem programmed to make ethical mistakes. And the ethical issues of future mass migration will surely be the most contentious of all.

Perhaps most perplexing will be the ethical quandary posed by the real-life application of *Star Trek*'s "Prime Directive" — noninterference with other cultures. Habitable planets may already be inhabited. Indigenous cultures may not welcome a mass immigration. While communicating with an alien civilization may be possible, negotiating a planetwide land-lease agreement might not be possible. Unless, perhaps, the inhabitants are close relatives.

Freeman Dyson, one of the most forward-looking of present-day physicists, imagines that the galaxy will already be populated by human colonists. As soon as space-travel technology permits, he believes, many adventurers will depart the planet for

other reasons long before hot weather forces an involuntary evacuation. If a similar spirit of adventure extends to alien civilizations, they conceivably could be headed our way as well.

"Within a thousand years, our descendants may be so widely dispersed that no central authority will be able to regulate their activities or even be aware of their existence," Dyson wrote in his 1997 book, *Imagined Worlds*. By 100,000 years from now, the whole galaxy may become one big astro-urban sprawl. So just as with the American West, pioneers may pave the way for a grand migration to follow.

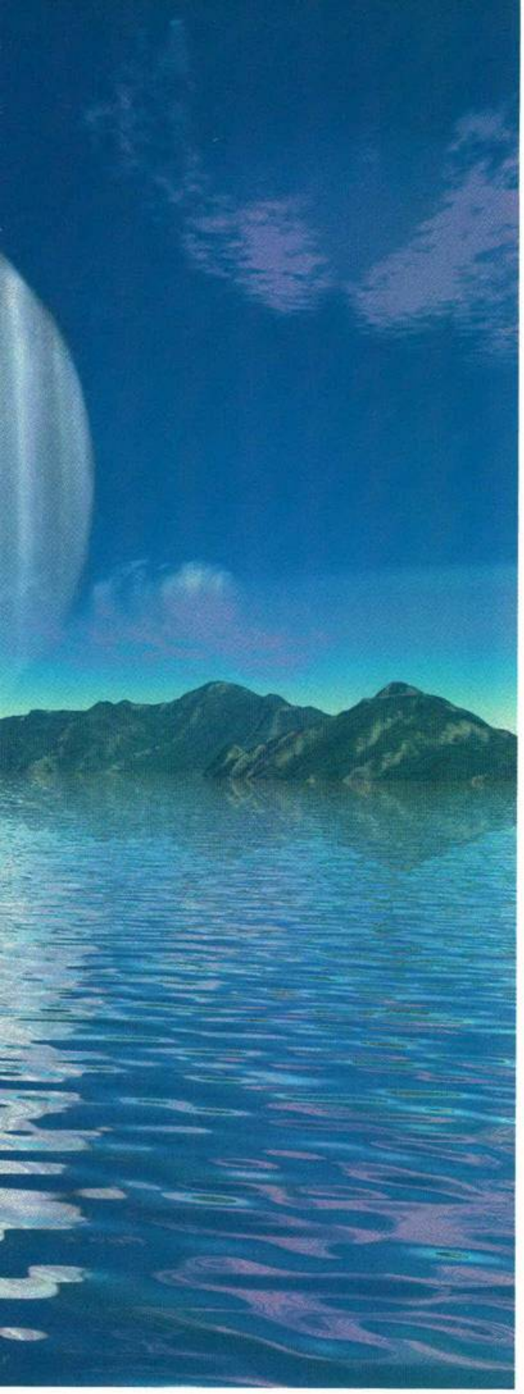
Unfortunately, just as with the American West, serious risks will be inherent. Interstellar flight technology could present an especially thorny problem in that they might represent vast interstellar bombs.

If we assume that colonists will travel at a significant percentage of the speed of light — possibly a naive presumption — their spacecraft would be a doomsday machine as well. A ship merely the size of the space shuttle, crashing into Earth at 30 percent of the speed of light, would cause about as much damage as the asteroid that may have done in the dinosaurs.

NEW COLONISTS

A decision to develop such technology is, therefore, a decision to produce weaponry of unprecedented destructive force. It would be nice to imagine that a society capable of such technology would possess the wisdom not to misuse it, but human history is not very comforting in that regard. In fact, the first space colonists may consist largely of malcontents — as with the colonizing of the Americas. Historian Page Smith has chronicled the high percentage of convicted felons and "the rather commodious category of rogues and vagabonds" who came to America once transoceanic travel became feasible.

"These were the hippies and dropouts of 17th- and 18th-century English society, the men and women so alienated from the dominant culture



Based on our experience on Earth, scientists expect that a habitable planet is one with a solid surface and liquid water.

that they had devised their own," Smith wrote. In the future, the human cousins occupying the galaxy's planetary sanctuaries might be similarly antagonistic to the culture from which they escaped. Particularly in light of the vast time and distance scales involved in interstellar migration, there is no guarantee that the original colonists will welcome migrants from Earth millennia later.

In fact, the colonists might perceive Earth as a threat and may try to harm it or its human inhabitants. Possibly, such concerns will retard or even prohibit the early colonization of space, leaving Earth fully populated when the sun heats up the migration controversy. Once departure becomes a matter of survival, the ethical question may shift to who should be assigned to a limited number of seats.

Whatever technology is available by then, it may not be possible to evacuate the planet's entire population. Choices may be made on a more complicated basis than "women and children first." Who will go? The wealthy, the well-connected? The scientists and technologists who made space travel possible? Many of the young, with a few of the old? If space on the interstellar express is limited, arguments about who gets to go may very well last for half a billion years.

On the other hand, if the United States, which spends about $100 million to carry 10 people aboard a shuttle, spent half of its $2 trillion annual budget on the exodus, it could send 100,000 people a year into space. In a mere 100,000 years, the country could send 10 billion people into space.

Present-day dilemmas may dissolve with future changes in the human race itself. What will the human species look like in 100,000 years, or in half a million millennia? Evolution may transform the face of humanity dramatically. The descendants of humans then may be as different from us as we are from jellyfish.

The most likely scenario, however, is not one of ordinary evolution, but of humans engineering their own future. Visionaries today dream of a genetically designed populace free from disease and pain. But genetic engineering will no doubt be used for other than medicinal purposes. Whatever abilities and behaviors that society decides to value, bioengineers may provide.

CEREBRAL CHIPS

Ultimately it will become questionable whether the future inhabitants of Earth will properly be called people. Clear signs exist that suggest genetic and computing technology might merge to create human-silicon hybrids. The lifeforms most likely to rule the planet in millennia to come may trace their ancestry to Microsoft.

Already scientists know how to connect nerve cells to computer chips. Electrodes on the scalp can read the minds of paraplegics to move a cursor on a computer screen. Growing networks of nerve cells in symbiosis with transistors is now the subject not merely of science-fiction novels, but of research grants.

Dyson has imagined brains with electronic implants, enabling person-to-person radio signaling, or "radiotelepathy." "It's going to take a long time," he says. "I say give it 50 years. But it doesn't seem unreasonable that it could happen." Furthermore, he says, it might be possible to genetically engineer radio-signaling ability, exploiting proteins with electrical properties found in other life-forms. "We know electric eels can do amazing things," he says.

The merger of computers with brains could create a neuronic mix of mental capacity and interindividual communication. The World Wide Web could become a World Wide Brain, with a "collective consciousness" that Dyson thinks would "enormously enlarge the scope of art, science, religion, and history."

If so, the beings that depart Earth millennia from now will resemble 20th-century humans only dimly, if at all. But with their powerful collective memory, they should at least recall that 20th-century humans were the first to realize that someday every earthling would have to depart the planet of the species' birth.

After all, the 20th century will no doubt be recorded as a great era of discovery — of the genetic engine driving life, the relativistic nature of time and space, the quantum nature of reality, the computational power of electronics, and the vastness of the universe. These findings form the foundation of the knowledge needed to cope with Earth's future inhabitability.

So when the time comes, our descendants will probably be ready. But only if human society in the future continues the course set by 20th-century science. We can't take flight to another planet now, but we can and must keep taking small steps in the right direction. In other words, as a species we must continue to look to the stars, because someday — and sooner than we might have imagined — that's where we're going to have to go.

Tom Siegfried is science editor at the Dallas Morning News. *His book,* The Bit and the Pendulum, *is to be published this month by John Wiley & Sons.*

When the

SOLAR WIND BLOWS

Business looks brisk for Jo Ann Joselyn, who predicts the weather in space.

by Katy Human

Jo Ann Joselyn is so nice that she speaks up for pigeons. As an astrogeophysicist, it's her job to speak up for astronauts, satellite operators, and utility companies, but pigeons seem beyond the call of duty.

Colleagues refer to her as the conscience of her field because she refuses to dismiss either the little guy or the big questions. Until recently, she was senior space scientist at the Space Environment Center — the space counterpart to the National Weather Service. Joselyn isn't studying mere hailstorms, however. She and other space-weather forecasters try to predict and understand the vast clouds of charged particles from the sun that occasionally pummel Earth's magnetic field.

Several years ago, Bruce Tsurutani, a physicist with NASA's Jet Propulsion Laboratory, was working with Joselyn on a research paper about how solar storms can affect Earth. Tsurutani raised his eyes at a sentence or two that Joselyn had included about pigeons.

"There was a reference to homing pigeons getting lost during magnetic storms," Tsurutani says. "I thought that this was not too germane to the topic and suggested deleting this part of the text.

"Boy, did I hear it from her!" Tsurutani laughed. With characteristic good humor and a touch of sternness, Joselyn informed him that

Portrait photo by Jonathan Kastner

Wade B. Clark, Jr.

Although geomagnetic storms have few visible effects, the aurora is a notable exception. Aurorae occur when charged particles from the sun collide with atoms and molecules in our atmosphere.

Russ Sampson

The yellow-green color seen in aurorae comes from oxygen atoms 60 to 150 miles high.

homing pigeons can be worth thousands of dollars. The birds find their way by orienting with Earth's magnetic field. So when the stormy sun stirs up that field, the poor pigeons may never make it home.

"Well, the sentence stayed," Tsurutani says ruefully.

The geomagnetic storms Joselyn studies are invisible, except for their showy by-products, aurorae. But a bad storm can shake the planet's magnetic field strongly enough to short-circuit power grids across North America or drench an unprepared astronaut in a lethal shower of high-energy radiation. So Joselyn and other space-weather forecasters try to give astronauts, power companies, and satellite operators ample time to protect their systems before the fireworks start.

When the sun's surface erupts in a flare or its larger cousin, a coronal mass ejection, particles speed away from the star like a gust of wind. But these winds, which consist mostly of electrons and protons, blow at hundreds of miles per second, and the high-energy particles can permeate the inner solar system. If conditions are just right when that gust smacks into Earth's magnetic field, it triggers a massive electrical disruption called a geomagnetic storm.

When this wind dumps its potent energy into Earth's magnetic field, aurorae light up the polar skies. The magnetic field funnels electrons and protons into Earth's upper atmosphere, where they strike atoms and molecules and cause them to glow with glorious colors. Joselyn describes Earth's magnetic field as the planet's protector. "It can take a little energy out of the solar wind," she explains. "And as it gets rid of the energy that it used to save us, we see an aurora."

FUN in the SUN

Joselyn has a way of finishing sentences with a small flourish of her hand and a verbal exclamation point. She speaks simply but eloquently and doesn't hide her fascination with the sun. In her neat, spare office in Boulder, Colorado, there's a ceramic sun on the wall, another one cut from metal, and a tasteful star crafted from fabric.

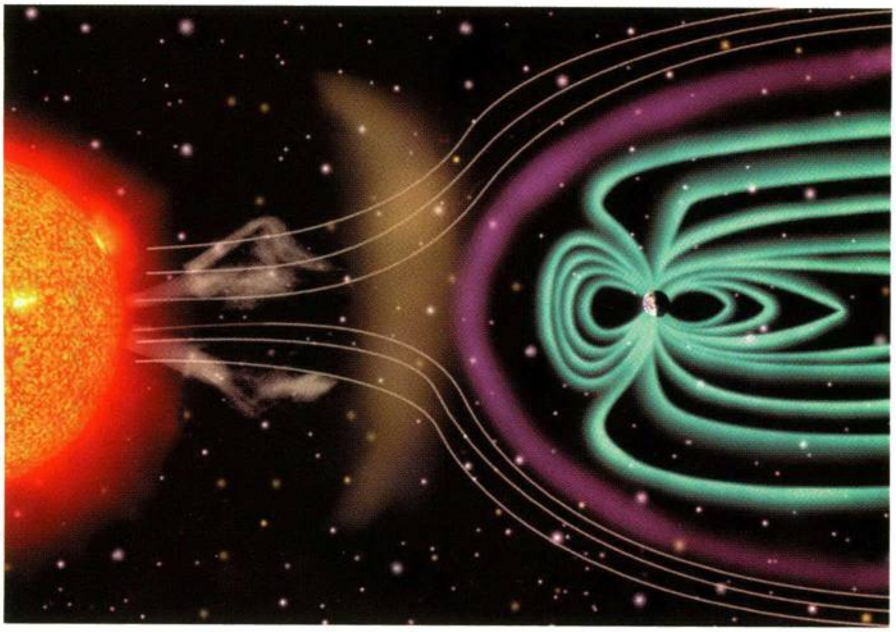
Joselyn, 56, admits she's been excited about the sun since college. As an undergraduate engineering student at the University of Colorado in Boulder, she signed up for an elective course in astrophysics. She didn't know it, but the professor had a habit of offering a research fellowship to his best student. "Well, I was that best student," Joselyn says, shrugging. "I just loved studying this stuff. I was so thrilled."

She completed a masters degree in astrogeophysics and took a job at the Space Environment Center, then called the Space Disturbances Laboratory. Don Williams, her boss, watched as Joselyn went back for a Ph.D. while still working part time at the laboratory. Now chief scientist at Johns Hopkins University's Applied Physics Laboratory, Williams calls Joselyn one of the most careful scientists he's known. And she's just tremendously nice, too, he added. "She has this capacity of putting people at ease."

Janet Luhmann, another colleague of Joselyn's, shared an example. "Jo Ann always invents new ways to control speakers who run on," says Luhmann, a research scientist at the University of California at Berkeley's Space Sciences Laboratory. "There's one where she has colored cards that are green, yellow, and red, and she holds them up in stages as she's sitting in the audience. Then I've seen her hold up applause signs so the audience begins to applaud and the speaker gets the hint. Everyone takes it in stride because she's so nice about it."

Joselyn says people have always been surprised she's a physicist. Maybe it's because of her delightful tinkle of a laugh. "I'm not particularly nerdy," she admits. But she is an extraordinarily capable communicator. Joselyn can explain the sun to a 5 year old or a Ph.D. astrophysicist.

To John Kappenman, that skill is invaluable. "It is very difficult to explain to upper management in an electric power company that they have to worry about solar activity 93 million miles away," says Kappenman, space weather manager for an electrical consulting firm called Metatech. "Jo Ann is able to relate with them."



Steele Hill, Raytheon ITSS/NASA

The solar wind (white lines) and more powerful coronal mass ejections (not to scale) permeate the inner solar system, including Earth, but our magnetosphere (turquoise lines) helps to protect us.

Jonathan Castner

Astrogeophysicist Jo Ann Joselyn wants to understand how solar storms affect Earth.

Kappenman says he met Joselyn just after the Quebec power outage of March 1989. A huge gust of solar wind buffeted Earth's magnetic field and induced electric currents in northeastern power grids, plunging Quebec into a blackout that lasted much of a day.

BLOWIN' in the WIND

Joselyn worries the winds may blow stronger this year. The year 2000 represents a peak in the 11-year cycle of the sun. At solar maximum, sunspots dot the face of our star like blemishes on a teenager's face. And the solar flares and coronal mass ejections that accompany those sunspots can cause problems.

"With solar maximum there can be a combination of effects that come together to make what we are calling our doomsday scenario," Joselyn says. In that scenario, increasingly frequent flares will blot out radio communication, and recurrent coronal mass ejections will threaten space-station astronauts, satellites, and power grids.

It would take an incredibly stormy sun to truly wreak havoc on Earth, Joselyn says. "This would be a rare situation. . . . I do want to say that conditions can be extreme, but I don't want to frighten anyone unnecessarily."

One condition is disruption of radio communication. Normally, transmitters bounce radio signals off the ionosphere to get them to radio antennae, just as pool players bounce balls off bumpers to get them into pockets. But when the high-energy particles from a solar flare disturb the ionosphere, an ionized region of Earth's upper atmosphere, it gobbles up radio transmissions.

It's coronal mass ejections, though — which release huge quantities of high-energy particles — that cause the most serious effects. Joselyn and other forecasters use real-time images of the sun and information from sun-orbiting spacecraft to determine when streams of particles and gusts of solar wind are heading toward Earth. Forecasters can usually alert clients a day or two in advance about mass ejections that might be heading our way, and they issue warnings about 30 minutes before a strong solar wind reaches the planet.

That's just enough time for power utilities to prepare for a geomagnetic storm, Joselyn says. And enough time to tell people to look for the aurora.

Politically as well as scientifically, Joselyn knows how to dodge storms with style — an excellent talent for her next job. Last July, Joselyn became the new secretary general of the International Union of Geodesy and Geophysics, the world's premier nongovernmental organization dedicated to understanding the planet.

"This will be the last stage of my career," she says. I've had the research phase and the practical phase and now this will be the leadership phase."

"I think she's ideally qualified," Tsurutani says of his colleague. "She's energetic and she gets things moving."

Luhmann says Joselyn's role as the "great conscience" in her field is her most important qualification. "Jo Ann challenges people constantly," Luhmann explains. "There's a tendency in scientific research sometimes to crank away and do things you're familiar with instead of confronting the big problem questions. Jo Ann keeps bringing up these big problems. She keeps reminding us of observations that might be clues."

Joselyn will be the first female secretary general of the IUGG.

"It's funny," she says. "I never felt particularly like a barrier buster." She is, of course: First woman to graduate with a Ph.D. in astrogeophysics at the University of Colorado. First woman to serve as secretary general of the International Association of Geomagnetism and Aeronomy.

Joselyn jokes that she fits the Janet Reno model of women: "postmenopausal and childless." Her 14-year marriage didn't survive graduate school, she says, leaning back a little in her chair. She was pretty intense about her work. But as secretary general of the IUGG, she'll get to travel frequently and connect with researchers of all sorts — two things she loves.

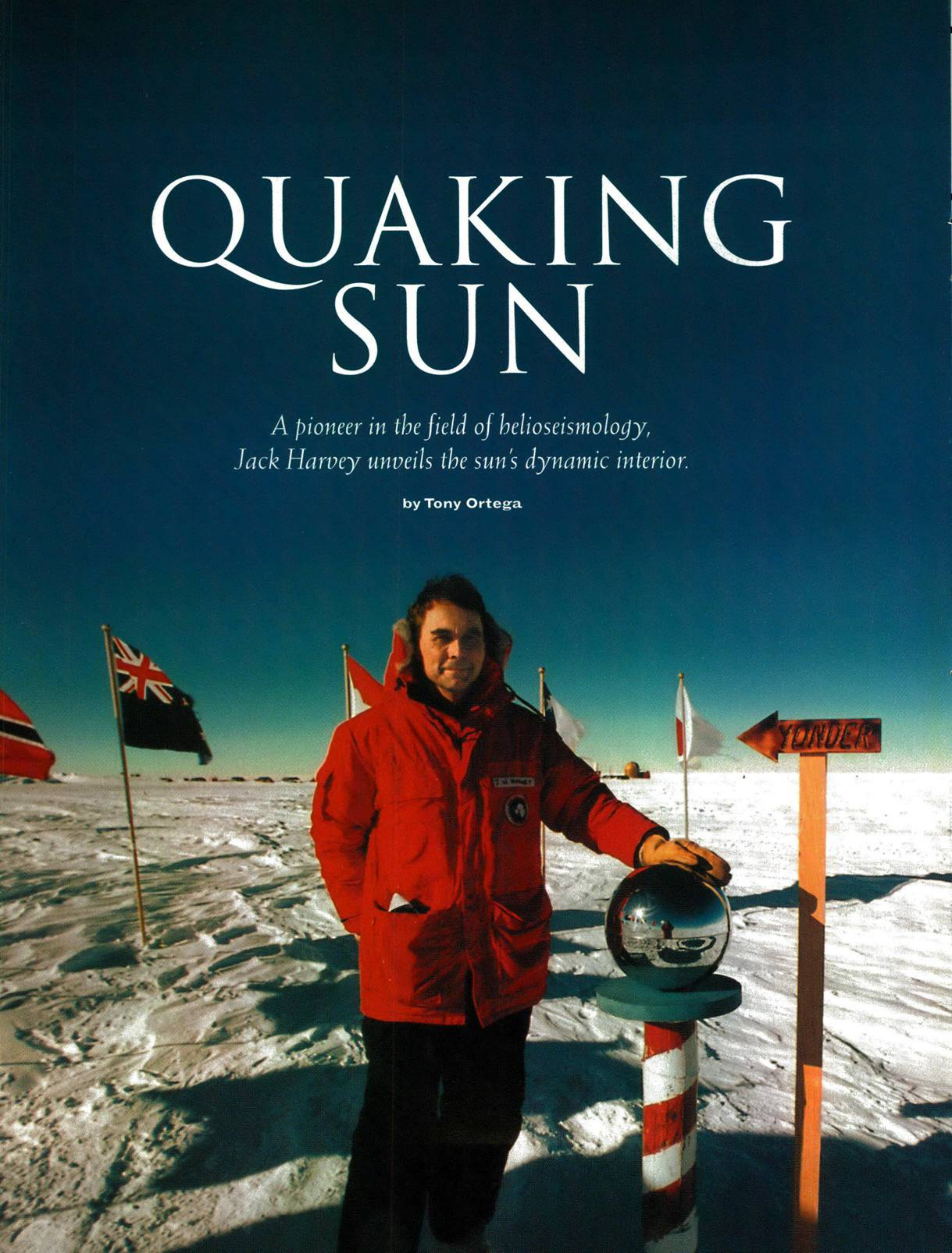
"The world's an oyster," Joselyn says. "Go for it!"

Katy Human is a science and environmental writer in Boulder, Colorado.

QUAKING SUN

A pioneer in the field of helioseismology, Jack Harvey unveils the sun's dynamic interior.

by Tony Ortega



Jack Harvey was among the first to peer beneath the surface of the sun and peel away its layers like a gigantic onion; he daily observes the sun's powerful magnetic field as the star is rocked by explosions with the equivalent energy of 400 billion Hiroshima atomic bombs; he is largely responsible for developing the science of measuring the humming, vibrating surface of the sun as it oscillates in 10 million different registers, yet this intrepid solar explorer admits he still puts on sunscreen before working in his garden.

You get the feeling Jack Harvey would rather stare directly at the sun without eye protection than take credit for his accomplishments. But his colleagues insist that Harvey, 58, is a key figure in deciphering some of the sun's greatest mysteries, such as the nature of its complex magnetic field and the structure of its interior.

Harvey is so well respected that he was recently chosen to receive a special edition of the solar field's highest award, the George Ellery Hale Prize. To the solar community, the Hale Prize is something akin to an Academy Award for lifetime achievement. The Hale Prize has been given every year or two since 1978 to solar physicists and other sun-related scientists at the ends of their careers.

Privately, some astronomers had taken to calling it the "Geezer Prize," a sort of astronomical gold watch and pat on the back for a job (long since) well done. But 1999 would be the centennial of Hale's founding of the American Astronomical Society, and scientists wanted to commemorate that anniversary by breathing new life into the prize. They wanted to give it to someone who not only had done great service to the field, but who was also currently at the top of his game. Jack Harvey was the obvious choice. Well, except to Harvey.

"Many more deserving solar scientists were nominated for this award," Harvey told the audience gathered to see him accept it on May 31, 1999. "I know because I wrote the letters of recommendation for some of them," he quipped.

"I'm not sure why they picked me," he tells *Astronomy*. "I dabbled in several things in my career and made a few discoveries of my own, but mostly I've been riding on the coattails of other people." He may be right; like other fine scientists Harvey is indebted to men and women who came before him. But then Isaac Newton also said he was able to see farther because he was standing on the shoulders of giants.

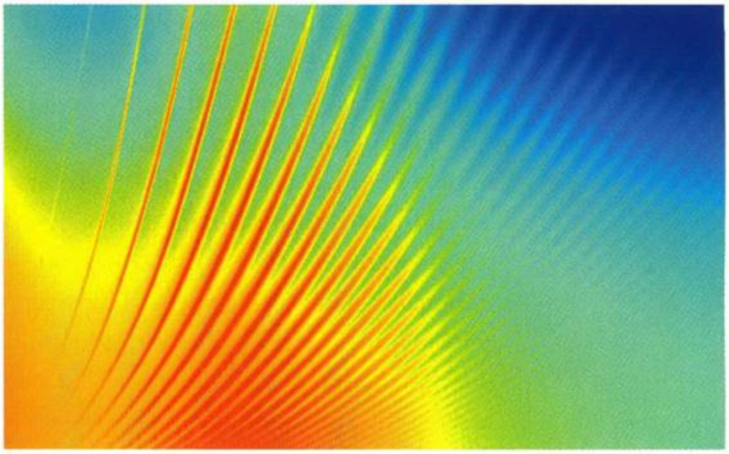
"Self-effacing to a fault," is how fellow solar physicist John Leibacher describes his colleague. Leibacher and Harvey both work at the National Solar Observatory on Kitt Peak, Arizona, where they lead an effort to produce a globe-circling network

Jack Harvey stands at the South Pole's ceremonial marker. He says the photo qualifies as "what are jokingly called 'hero' pictures by folks visiting the pole." Don Neff

SOLAR SYMPHONY

The sun is filled with sound. Its spherical harmonics resonate with 10 million notes that provide a glimpse into the sun's violent interior. The study of these "sound" waves is called helioseismology.

On Earth, seismic waves are generated by no more than a few sources — an earthquake or the movement of magma are two examples. On the sun, no single source produces solar seismic waves. Instead, the sun rings like a bell being continually struck with many tiny sand grains. The compositions, densities, temperatures, and motions deep within the sun all influence the oscillation periods of these waves.



Only waves with specific combinations of periods and horizontal wavelengths resonate within the sun. The precise combinations are related to the sun's interior. They produce the standing sound waves, or "ridges," seen in the graph above. The strongest movements are red while the weakest movements are blue.

Helioseismology also allows astronomers to decipher how the sun's rotation changes with depth and latitude. Image 1 shows a clear change in rotation speed in the sun's convective zone (at roughly 45° north and 45° south latitude) and in between the convective and radiative zones. Red material is rotating faster than the blue areas at the poles.

1

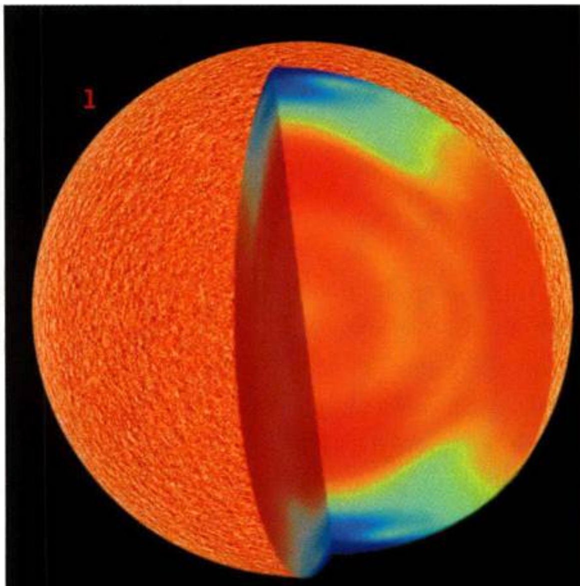
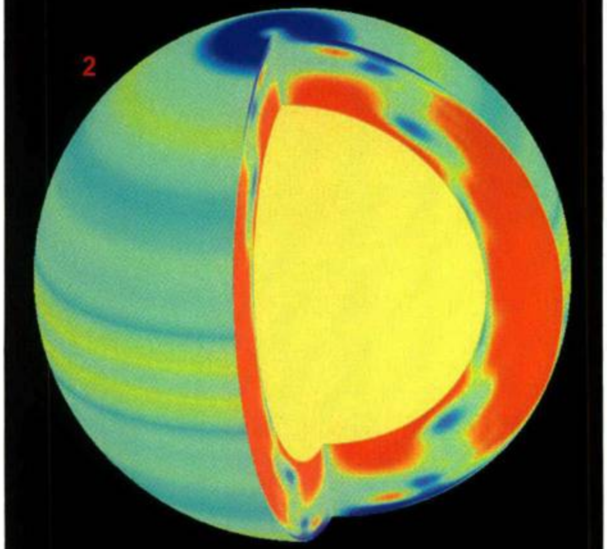


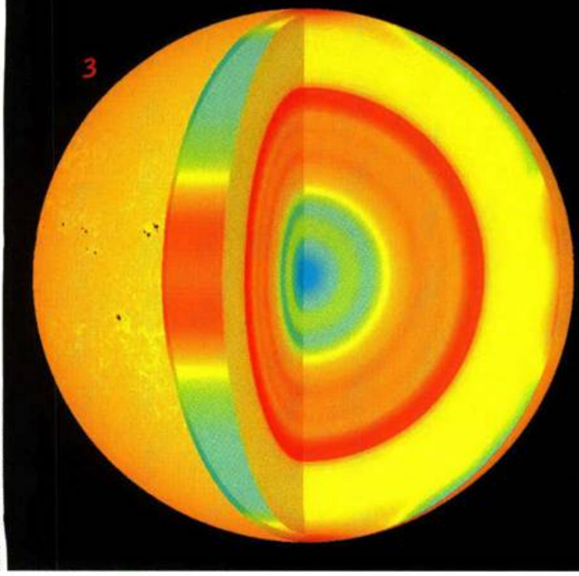
Image 2 also represents speed differences. Red-yellow is faster than the average speed, while blue is slower. The yellow-orange bands on the surface of the sphere (left side) are moving slightly faster than their surroundings. The cutaway (right side) reveals speed variations in the sun's interior. Red ovals embedded in the green areas at the poles are newly discovered polar plasma "jet streams." They move roughly 10 percent faster than their surroundings. Each is about 17,000 miles across and large enough to engulf two Earths.

2



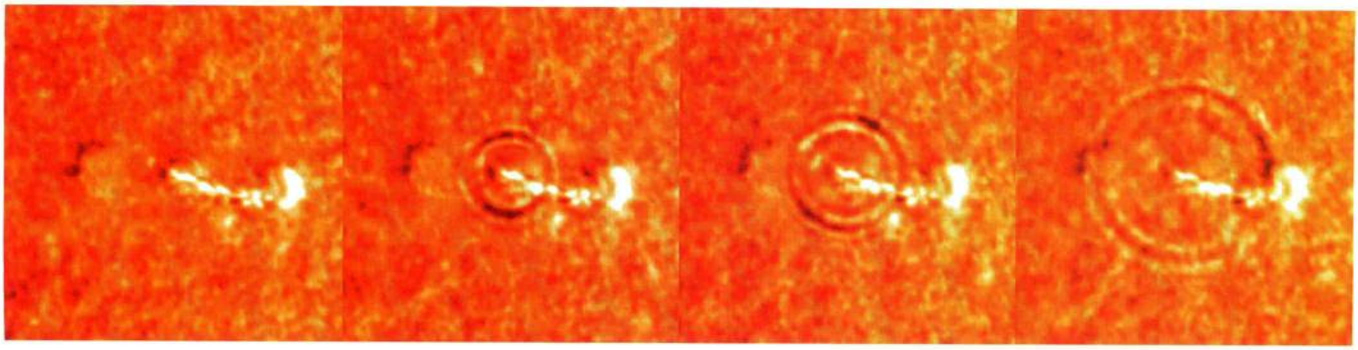
Finally, image 3 reveals the speed of sound in the sun's interior. Sound moves faster than helioseismologists expected in the red layers, implying higher temperatures. The bright-red band marks the transition between the radiative and convective zones. In blue regions, sound moves slower and the temperatures are cooler than expected, most notably in the core, where they may be one-tenth of a percent cooler than the expected 15 million degrees.

3



—Andrea Gianopoulos

NASA/SOHO/MDI Consortium



This rapidly expanding "sun quake" was recorded by Michelson Doppler Imaging on July 6, 1996. The seismic wave, which was created by a moderately sized solar flare, spread more than 62,000 miles over the solar surface. Though they look like ripples spreading from a rock dropped into a pool of water, these solar waves accelerated from an initial speed of roughly 22,000 mi/hr to a maximum of nearly 250,000 mi/hr before disappearing. Water ripples travel outward at a constant velocity. NASA/SOHO/MDI Consortium

of solar observing stations to keep the sun under constant surveillance. Leibacher says it was characteristic of Harvey that he insisted data from the project should be shared with the entire solar community. "If there were more scientists like Jack and fewer of the big egos out there, a lot more would get done," said one astronomer who didn't want to be named. Another solar physicist, Montana State University's Richard Canfield, says few scientists are as versatile as Harvey. "Jack is probably one of the broadest people in our discipline in terms of what he has done scientifically in his career. It's awesome. There are people who have just worked on solar flares. There are people who have just worked on helioseismology. There are people who have just worked to develop instrumentation. Jack's done all those things."

Harvey remembers that it was an early 1950s trip to California's Mt. Wilson Observatory and a conversation with solar astronomer Joe Hickox that prompted his fascination with the sun. "He showed me interesting things such as the solar spectrum, sunspots, the sun in H-alpha. And this was so exciting — it certainly influenced my career. I wanted to see more. I wanted to understand it," Harvey says. He also admits that there are perks to studying an astronomical object only 93 million miles away that is best viewed during convenient daytime hours. "Some fields of astronomy count photons one by one, but we count them by the pound," he says.

When he began his own career in solar physics, Harvey says he never dreamed that scientists would ever be able to peer beneath the 8,000° Fahrenheit surface of the star to study its interior. Today, that's possible. And largely because of Harvey's efforts in the development of a science called helioseismology.

The surface of the sun isn't really a "surface" at all. The sun's interior roils with convective layers of gases at extreme temperatures; 435,000 miles above the center of the star, those gases form a constantly oscillating surface that scientists call the photosphere. In the past 15 years, solar physicists such as Harvey have learned how to measure those oscillations. Like a seismologist studying tremors moving through rock and revealing something about Earth's interior, Harvey helped develop helioseismology to study the sun's vibrations for clues to the nature of its interior. Only it's not that simple.

To say the sun vibrates is to say the Milky Way has stars. "The sun has the ability to oscillate in 10 million different modes. It's like an organ pipe that 10 million different tunes can be played on," Harvey says. Still, he and others can measure those myriad oscillations and decipher what they say about the layers of gases below the photosphere. To do that, however, requires watching those vibrations for long periods of time, and that's a problem if you happen to be on a part of Earth where the sun spends only part of the day in the sky. Solving that problem is what sent Harvey to the South Pole for the first time in 1981. He made five trips through 1995, and his observations there proved that watching the sun throughout a 24-hour period offered a great advantage for helioseismologists. But Antarctica is a harsh environment, and observations of the sun can only be made there during its brief summer.

Back at Kitt Peak, Harvey, Leibacher, and others set out to find another way to keep the quaking sun under constant vigilance. The result is the GONG (Global Oscillation Network Group) Project, which watches the sun from six stations around Earth. Combined with data from various satellites that observe the sun without the hassle of an intervening Earth, GONG supports a community of 200 or 300 researchers interested in its observations.

"It's an exciting time, we're witnessing interesting theories," Harvey says. He's particularly enthusiastic about a new project that will enable American solar scientists to replace outdated equipment; new instruments Harvey is installing on Kitt Peak will soon enable him for the first time to make three-dimensional measurements of the sun's magnetic field before and during the gigantic explosions — called coronal mass ejections (CMEs) — that daily rock the day star. Harvey says a typical CME packs a 10-billion-megaton wallop and three or four of them occur a day, sometimes in association with solar flares and prominences. Harvey suspects the sun's magnetic field somehow produces CMEs, and his new instruments could solve several mysteries about them.

But even with his development of new instruments and new theories, Harvey says the sun is still largely an enigma. "We're incredibly ignorant about how the sun works. It's quite a challenge to understand how other stars work if we've learned so little about our sun. . . . We don't really understand even the basics of how the sun produces its series of cycles. That's still quite mysterious. We can't predict, for example, how intense a solar maximum will be. . . . The sun is the astronomical object that makes life possible on Earth. It's the one we should know the most about, but it's still a puzzle after all these years of looking at it," Harvey says. It's the mystery that drives him. That, and the convenience. "You get to work in the daytime," he says with a chuckle.

Tony Ortega is a journalist for New Times *in Los Angeles. His last story for* Astronomy *was "Comet Stalker," April 1999.*

UNDERGROUND ASTRONOMER

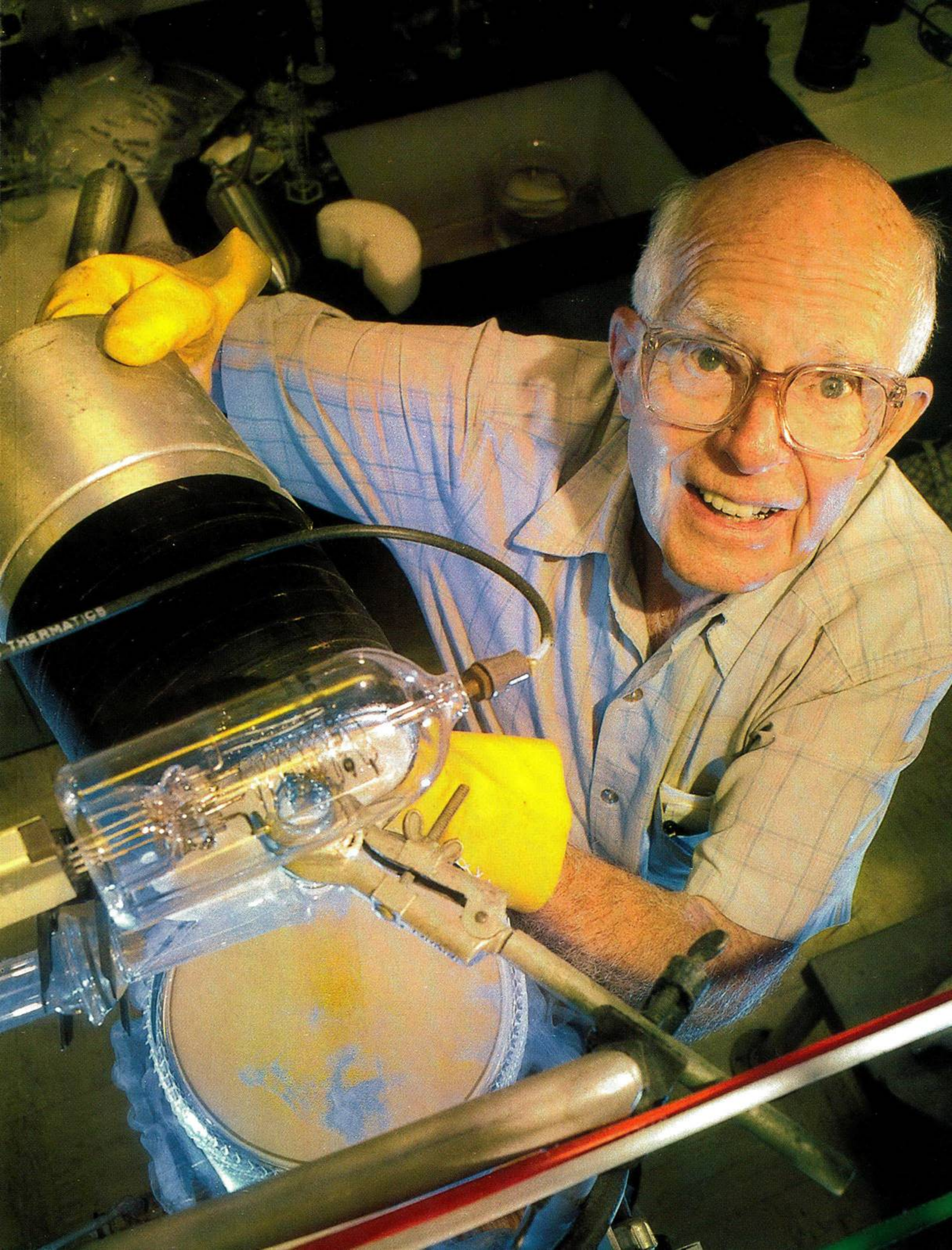
Ray Davis gave an active gold mine a second job — as a neutrino telescope.

by Marcia Bartusiak

Raymond Davis is famous for originating "underground astronomy." To examine the very heart of the sun, he went to the Black Hills of South Dakota in the 1960s and set up a detector nearly a mile below the surface. It operates to this day.

This solar telescope looks like no other on Earth. It resembles a huge, gray oil tank with rounded ends. Its construction crew affectionately called it "the horizontal blimp." Forty-eight feet long and 32 feet in diameter, this container is filled with 100,000 gallons of dry-cleaning fluid (perchloroethylene). Davis uses this chemical reservoir to trap neutrinos, the most ghostly particles in nature's arsenal. He's been gathering them, as they shoot through Earth, to understand the furnace powering the sun. His results have rattled solar physics for three decades, spawned even bigger subterranean neutrino observatories around the world, and forced particle physicists to rethink their notions about the lowly neutrino.

Roger Stoutenburgh/Brookhaven National Laboratory


THERMATICS

Sheer curiosity led Davis into his job as a solar-neutrino hunter. Trained as a chemist, Davis obtained his doctorate at Yale University, where he investigated the chemistry of soda water. World War II brought him to Dugway Proving Ground as an army liaison officer to the Air Chemical Office. After the war, he worked for Monsanto Chemical Company as a radiochemist, a job that deals with radioactive elements. By 1948, at the age of 34, he started what would become a lifetime career as a research scientist at the Brookhaven National Laboratory on New York's Long Island.

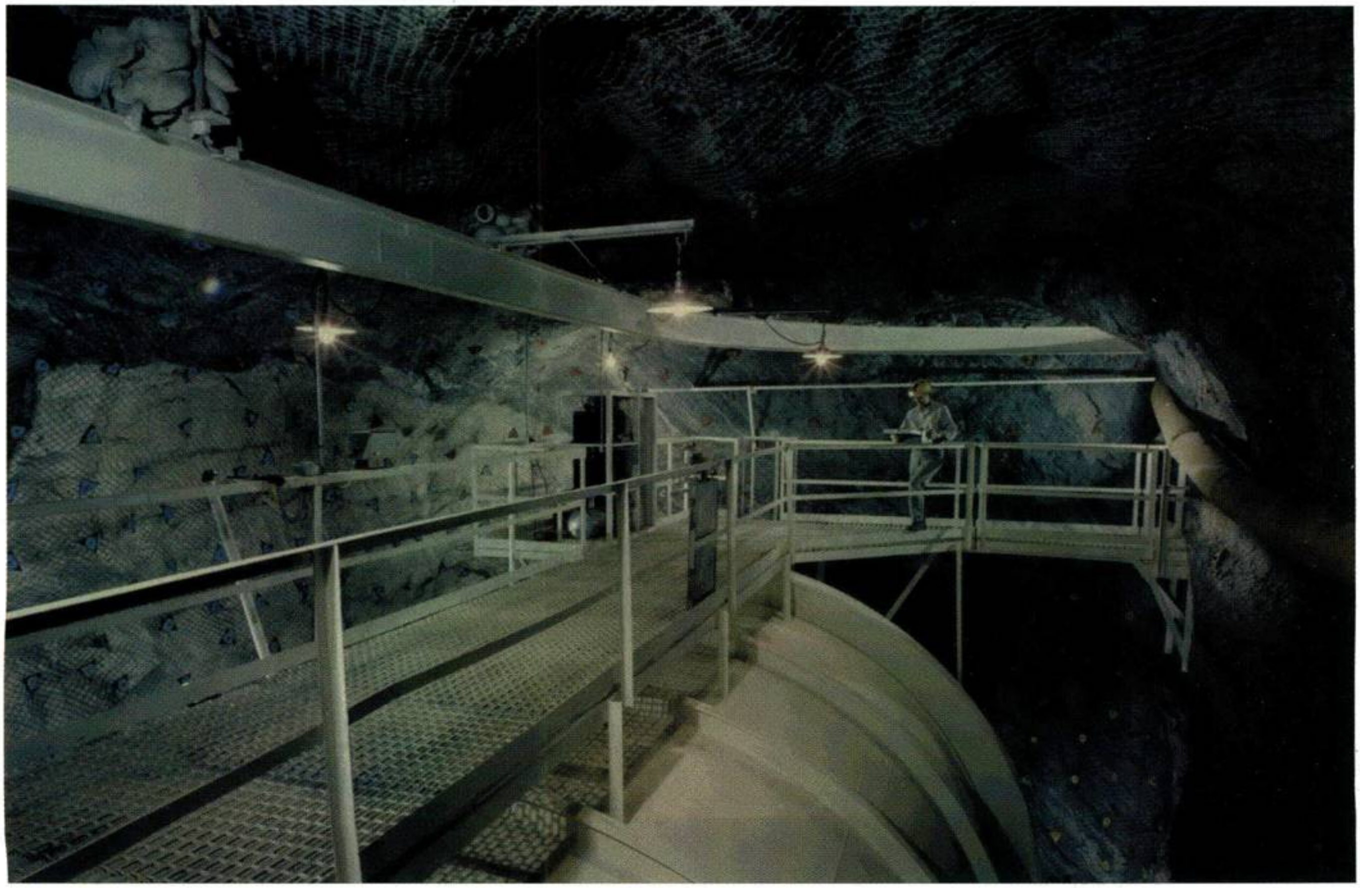
"It was the type of lab where you could choose your own problem," says Davis. He happened to read a journal article on neutrinos and was inspired to try to catch one directly. They were as yet unseen. The Viennese physicist Wolfgang Pauli first proposed the particle's existence in 1930 to explain an energy that is mysteriously lost during radioactive decay. As then conceived, the neutrino had no mass, no charge. It was merely an energetic mote, akin to a photon of light.

Davis's detectors were tanks filled with hundreds of gallons of carbon tetrachloride, set up first at Brookhaven then at the Savannah River nuclear power plant in South Carolina. A theorist had pointed out that when a neutrino bumps into a nucleus of chlorine, the chlorine would turn into traceable radioactive argon. It was the perfect strategy for Davis, given his background in radiochemistry. Normally, a neutrino is so elusive that it would take a stack of lead, hundreds of light-years in length, to stop one in its tracks. But Davis knew that the odds would be increased if a flood of neutrinos, such as one that might spew from an atomic reactor, is coming at you. He was in friendly competition with physicists Frederick Reines and Clyde Cowan, who were also at the plant looking for neutrinos but using a different method. In 1956, they won the competition and were awarded a Nobel Prize as well. However, Davis wasn't discouraged. He turned his chlorine-filled tank into a solar telescope.

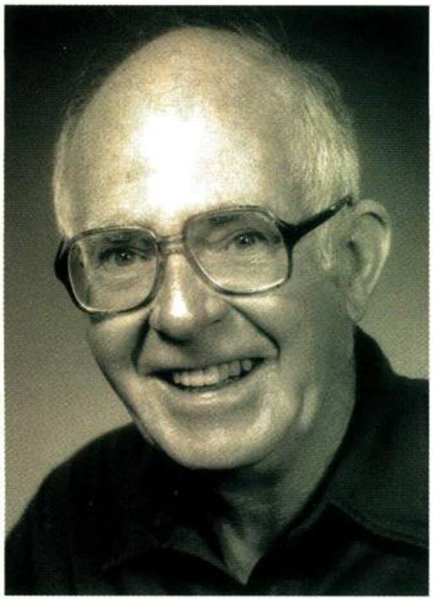
The sun, it turns out, is the best source of neutrinos for Davis's chemical method of detection. A preliminary search in an Ohio limestone mine turned up nothing. But by the 1960s, theorists at the California Institute of Technology were tinkering with their solar models and concluding that the sun should be emitting enough high-energy neutrinos for Davis to detect — if his tank were bigger. "Everyone was stirred up by the possibility," says Davis. Here was the chance to look directly into the heart of the sun. He decided on a 100,000-gallon tank, bigger than the theorists suggested. He didn't want to take the chance that they had overestimated the flux of neutrinos. He placed his tank 4,800 feet underground, far from disruptive cosmic rays, in South Dakota's Homestake Gold Mine. Miners carved out a special niche for it. The Atomic Energy Commission paid the bill for the ambitious enterprise.

"It cost about 60 Cadillacs," says Davis, around $600,000. Ten railroad tanker cars were brought in to fill the tank, this time with less toxic perchloroethylene as his source of chlorine, roughly the amount of stain remover American consumers use in 24 hours. Davis is proud to say "it has never leaked." One percent of Earth's atmosphere is argon, so a leak would have ruined the experiment. With the

Previous page: Raymond Davis continues his work at Brookhaven National Laboratory. Below: In the 1960s, the Homestake Mining Company gave Davis's neutrino telescope a home in its active South Dakota gold mine.

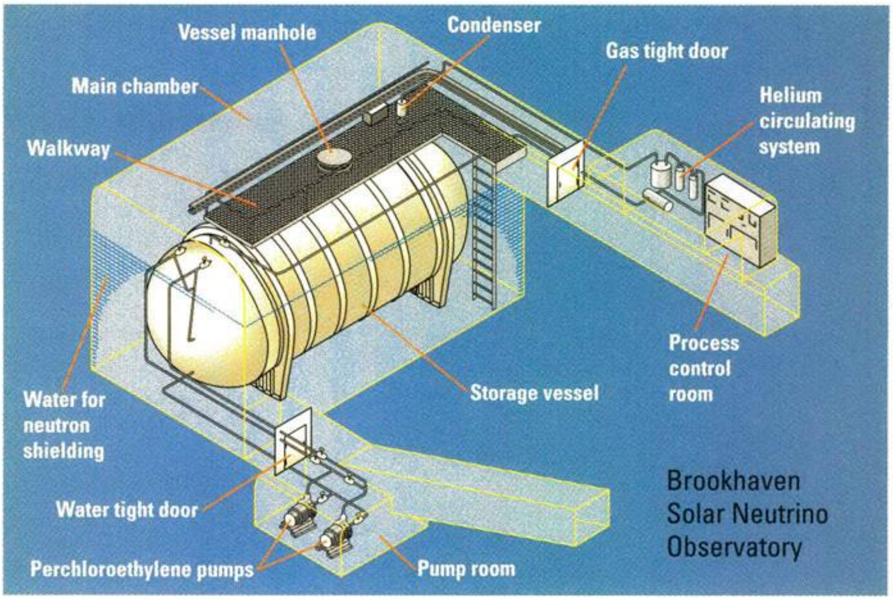


Brookhaven National Laboratory



Brookhaven National Laboratory

Raymond Davis is currently working on equipment that he hopes will count antineutrinos.



Astronomy: Terri Field

Original plans for the Davis solar neutrino telescope were drawn in the early 1960s. An early version was built at Brookhaven, then another at the Savannah River Nuclear Power Plant.

tank filled and the valves closed starting in 1967, Davis's team waited for the neutrinos to do their work.

Deep in the core of the sun, where temperatures reach up to 15,000,000° K, hydrogen nuclei — protons — collide and merge. During one second, half a billion tons of hydrogen are converted into helium, releasing a flood of neutrinos in the process. They escape with nary a fight, and each second 66 billion of them rain down on every square inch of Earth's surface and pass right on through. Occasionally, however, one will turn a chlorine atom into argon within Davis's tank. About every two months, the argon gets extracted by bubbling helium gas through the cleaning fluid. Sent through a cold trap, the argon freezes out of the gas.

By 1971, Davis had enough data to issue his first report. The results were surprising: The Homestake "telescope" was capturing about one neutrino every other day, between a third and a half of what solar physicists were expecting. Holding fast to their models of nuclear burning, theorists blamed either Davis's equipment or his chemistry. But after running numerous checks, Davis was sure his results were right. Solar physicists couldn't completely explain how the sun shined.

Over the next three decades, the Homestake result stood firm. Later, bigger and more sophisticated neutrino observatories were built in Japan, Russia, Italy, and Canada. They confirmed Davis's initial findings.

Although the controversy is far from settled, the most popular explanation for the shortfall arrives, not from solar physics, but from particle physics. Neutrinos come in three "flavors" (as theorists like to put it): the electron neutrino, the muon neutrino, and the tau neutrino. As the sun releases its storm of electron neutrinos, some might be changing their identity before they get to Earth, into the other flavors that the Homestake tank can't detect. And, to do that, the neutrinos must have a tiny bit of mass, a revolutionary finding. The cosmos released hordes of neutrinos at its birth. Given a little mass, this cosmic ocean of shadowy particles could be affecting the universe's evolution and destiny. And, to think, this revelation first arrived within a bit of cleaning fluid. Forced to retire from Brookhaven at the age of 70 in 1984, Davis has been carrying on his experiment as a research professor at the University of Pennsylvania. Now in his 80s, he can recall with vivid clarity the smallest technical detail of his instrument, as well as the names of every colleague who came to his aid. It has been his life for four decades. And it continues to be. From the home on Long Island he shares with his wife of 52 years, Anna, he commutes a few days a week to Brookhaven to work on equipment that may allow the Homestake telescope to count antineutrinos as well. (They turn chlorine into sulfur.)

The experiment was temporarily suspended for three years, due to a lack of money. But the University of Pennsylvania just received a grant to resume the operation for three more years, under the direction of Kenneth Lande. "I have a personal reason to continue it," says Davis. He is convinced that he is seeing the neutrino signal vary with the eleven-year solar cycle, and in an intriguing way. When the sun is most active — the number of its sunspots at its highest — he sees fewer neutrinos. The effect reverses when solar activity is on the wane. "It's a fairly good conclusion, but not everyone buys it," he says in his generous, self-deprecating manner. Moreover, he has also registered higher neutrino counts when solar flares pop off. His highest count occurred during a run in the 1970s when the sun emitted a particularly powerful solar flare. At the time, his tank registered double its normal count of neutrinos. But no other neutrino observatory is seeing either of these effects, although they are quite capable of doing so. Davis is determined to keep the Homestake telescope going to gather more data.

"Solar models are not perfect. We don't know what's happening in the core of the sun," he notes. "There's still a surprise there." Is he ready to go out to South Dakota again? "As soon as they give me an airplane ticket," he replies readily.

Contributing Editor Marcia Bartusiak is writing a book on gravitational-wave astronomy.

Ring in the New Year with some sparkling star clusters and a total lunar eclipse.

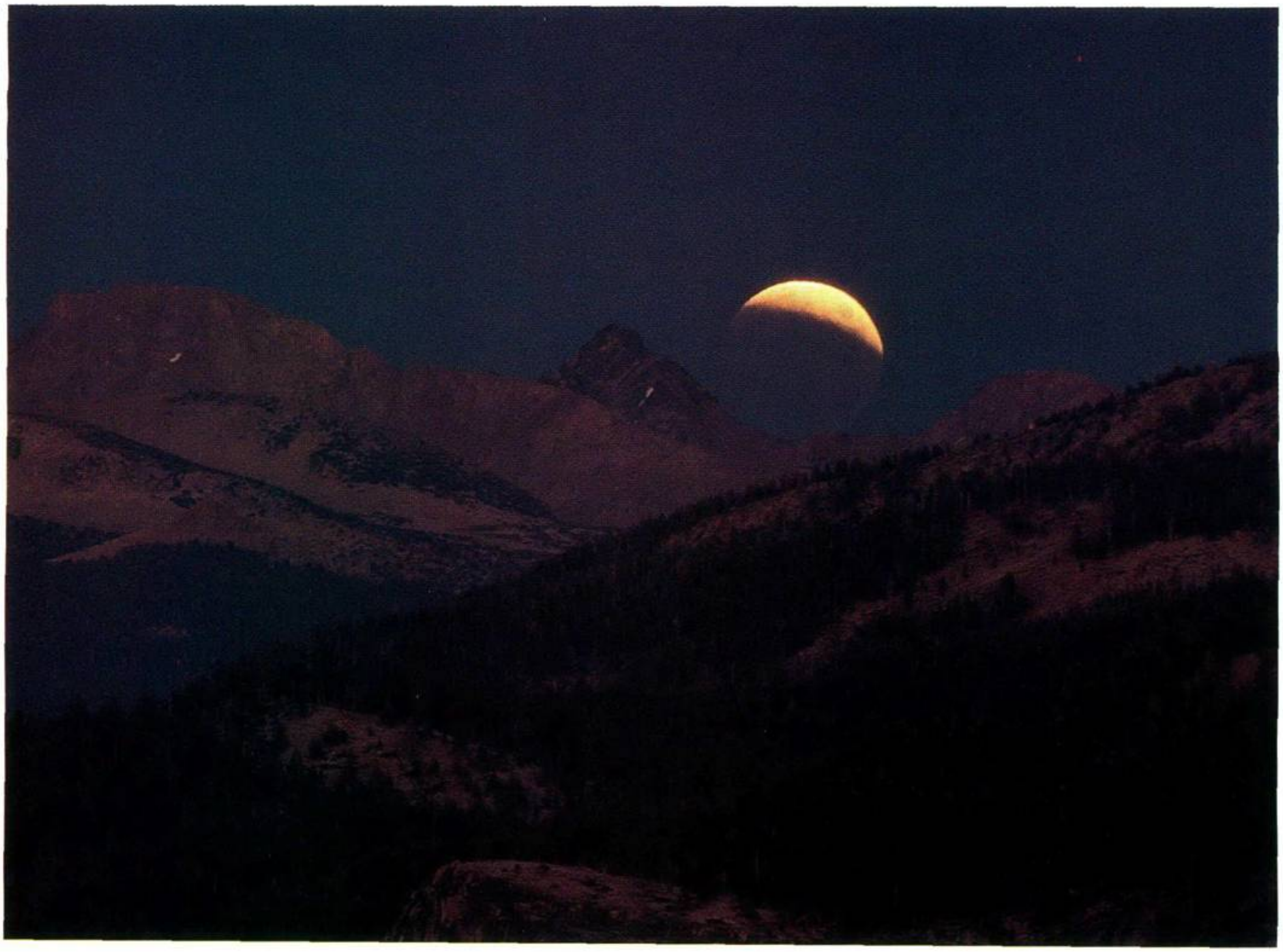
by Martin Ratcliffe and Alister Ling

▶ The New Year opens with North America's first total eclipse of the moon in more than three years. This spectacular event occurs on the evening of January 20 — perfectly timed for the whole family to view it. Make the most of this lunar eclipse, since the next one visible from the entire United States will not occur for another three years, on May 16, 2003. (Europe, however, will be treated to another total lunar eclipse on January 9, 2001.) This year's eclipse is also visible from Central and South America, Hawaii, and most of Africa and Europe.

The transition from a fully illuminated moon when only the brightest stars are visible in the sky to a dark-orange moon in a splendid, starry sky is a sight not to miss. A little understanding of what is actually happening enhances the event. During a total eclipse of the moon, our satellite passes into Earth's shadow, which at the distance of the moon happens to be close to three times the moon's diameter of half a degree. To imagine how this works, shine a flashlight onto an orange — the illuminated side represents the daytime side of Earth, and the dark hemisphere represents the nighttime side — notice that if you have a nearby wall, a circular shadow of the fruit apppears on the wall. This represents Earth's shadow. Anyone living on the nighttime side of Earth can observe the eclipse, unlike a total solar eclipse that is only visible from a very narrow but long track.

However, unlike our orange, Earth is enveloped in an atmosphere that acts like a lens and bends rays of light from the sun, enabling them to reach the moon. Red light, one component of the spectrum, is the only wavelength of light bent enough to reach the moon, hence the moon appears to be bathed in a copper glow.

A total lunar eclipse occurs this month when the sun, Earth, and moon align so that Earth's shadow is cast onto the face of the moon.



Howard Bruensteiner

JANUARY 2000

2 The moon passes 3° north of Venus, 11 P.M. EST
Earth is at perihelion (91.4 million miles from the sun), midnight EST

4 The moon is at apogee (252,536 miles from Earth), 7:23 A.M. EST
Quadrantid meteor shower peaks (page 77)

6 New moon is at 1:14 P.M. EST

7 Venus passes 7° north of Antares, 5 A.M. EST

8 The moon passes 0.2° south of Neptune, 1 A.M. EST
The moon passes 0.4° south of Uranus, midnight EST

10 The moon passes 1.9° south of Mars, 2 P.M. EST

12 Saturn is stationary, 9 P.M. EST

14 First quarter moon is at 8:34 A.M. EST
The moon passes 4° south of Jupiter, 10 A.M. EST

15 The moon passes 3° south of Saturn, noon EST
Mercury is in superior conjunction, 8 P.M. EST

17 Asteroid Melpomene is at opposition, 4 A.M. EST
The moon passes 1.2° north of Aldebaran, 3 P.M. EST

19 The moon is at perigee (223,297 miles from Earth), 5:49 P.M. EST

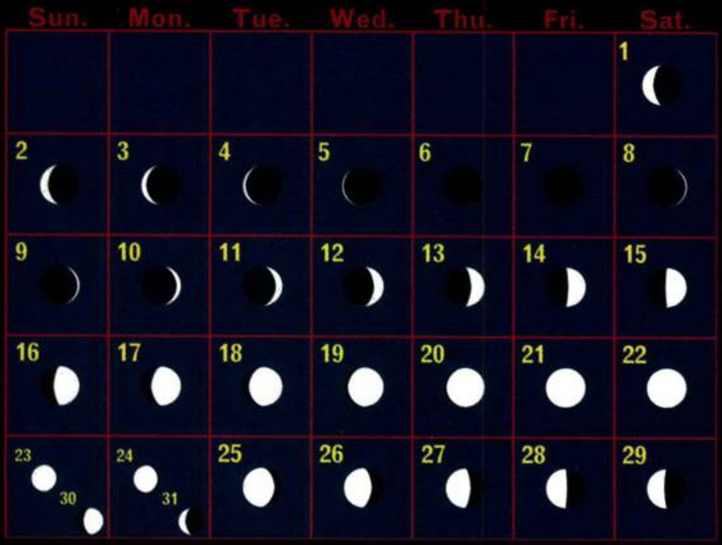
20 Full moon is at 11:40 P.M. EST; total lunar eclipse (page 73)

24 Neptune is in conjunction with the sun, 1 P.M. EST

26 Asteroid Pallas is at opposition, 10 P.M. EST

28 Last quarter moon is at 2:57 A.M. EST

31 The moon is at apogee (252,033 miles from Earth), 8:21 P.M. EST


Sun.
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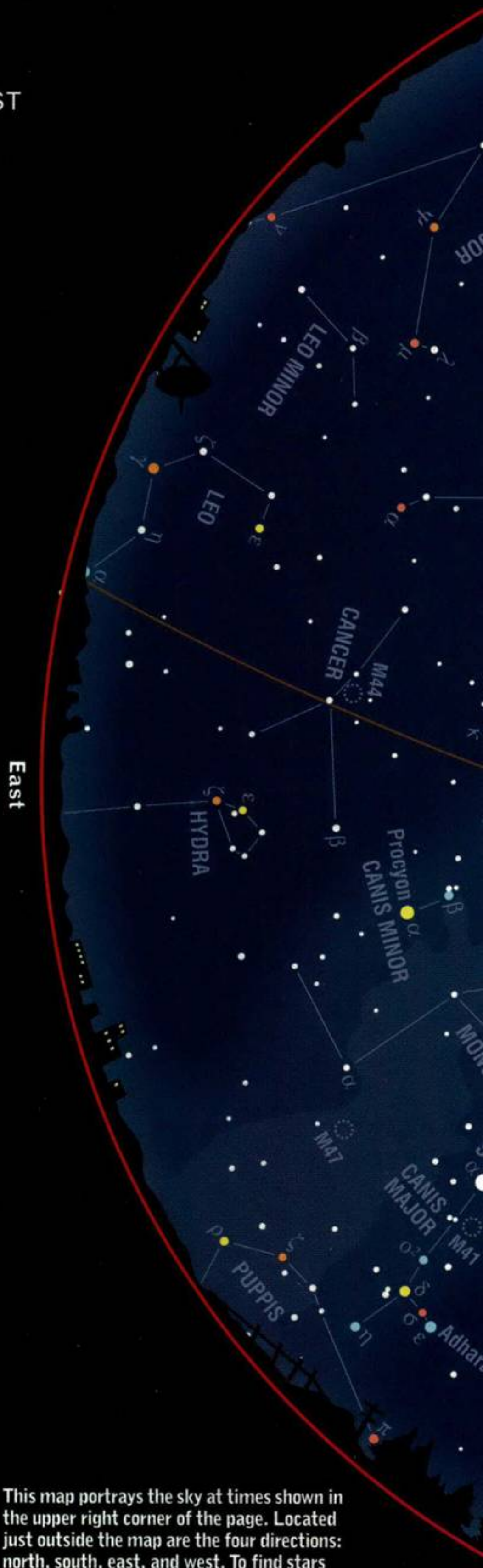
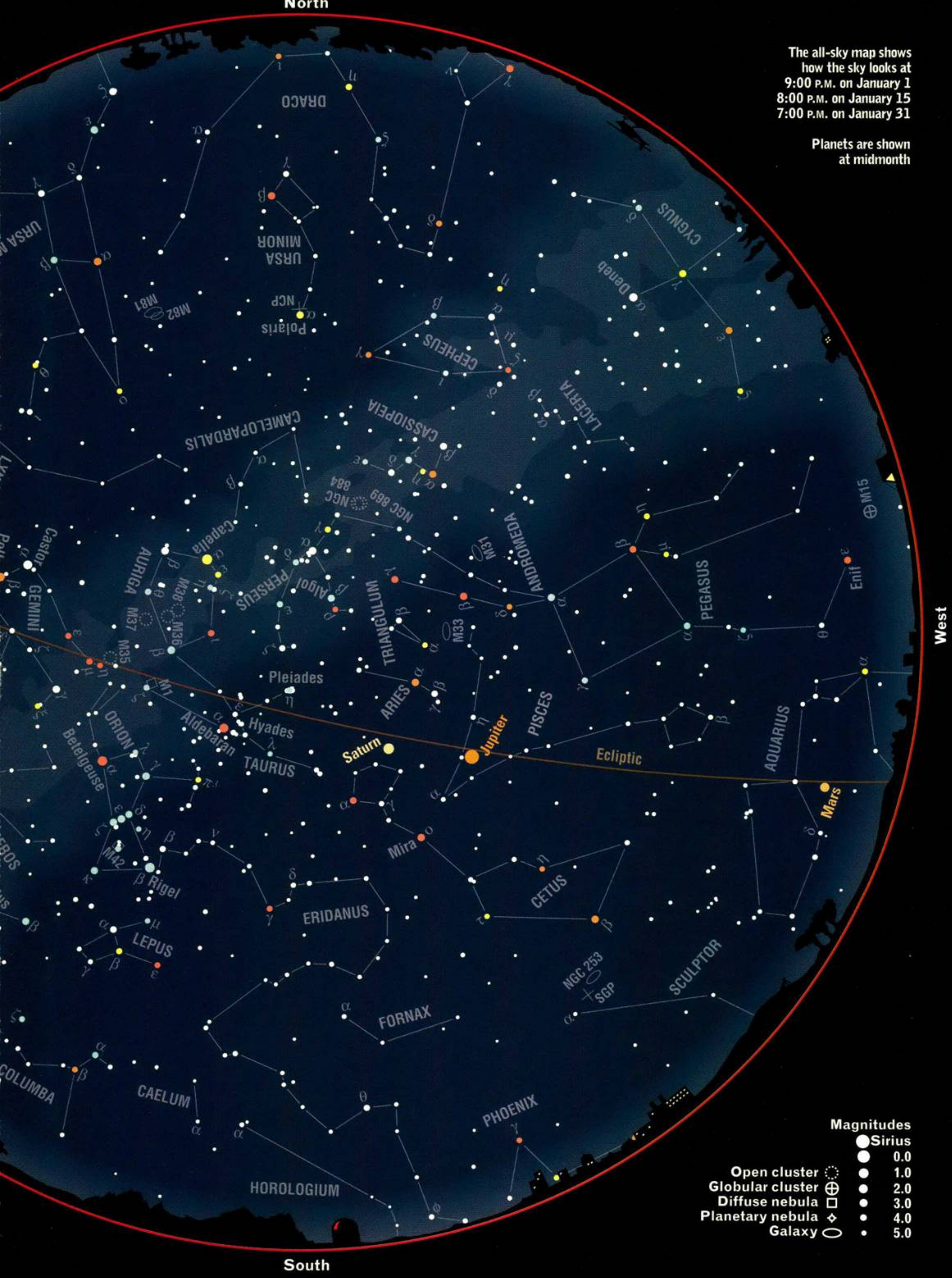

East
LEO MINOR
LEO
CANCER
M44
HYDRA
Procyon
CANIS MINOR
M47
CANIS MAJOR
M41
PUPPIS
Adhara

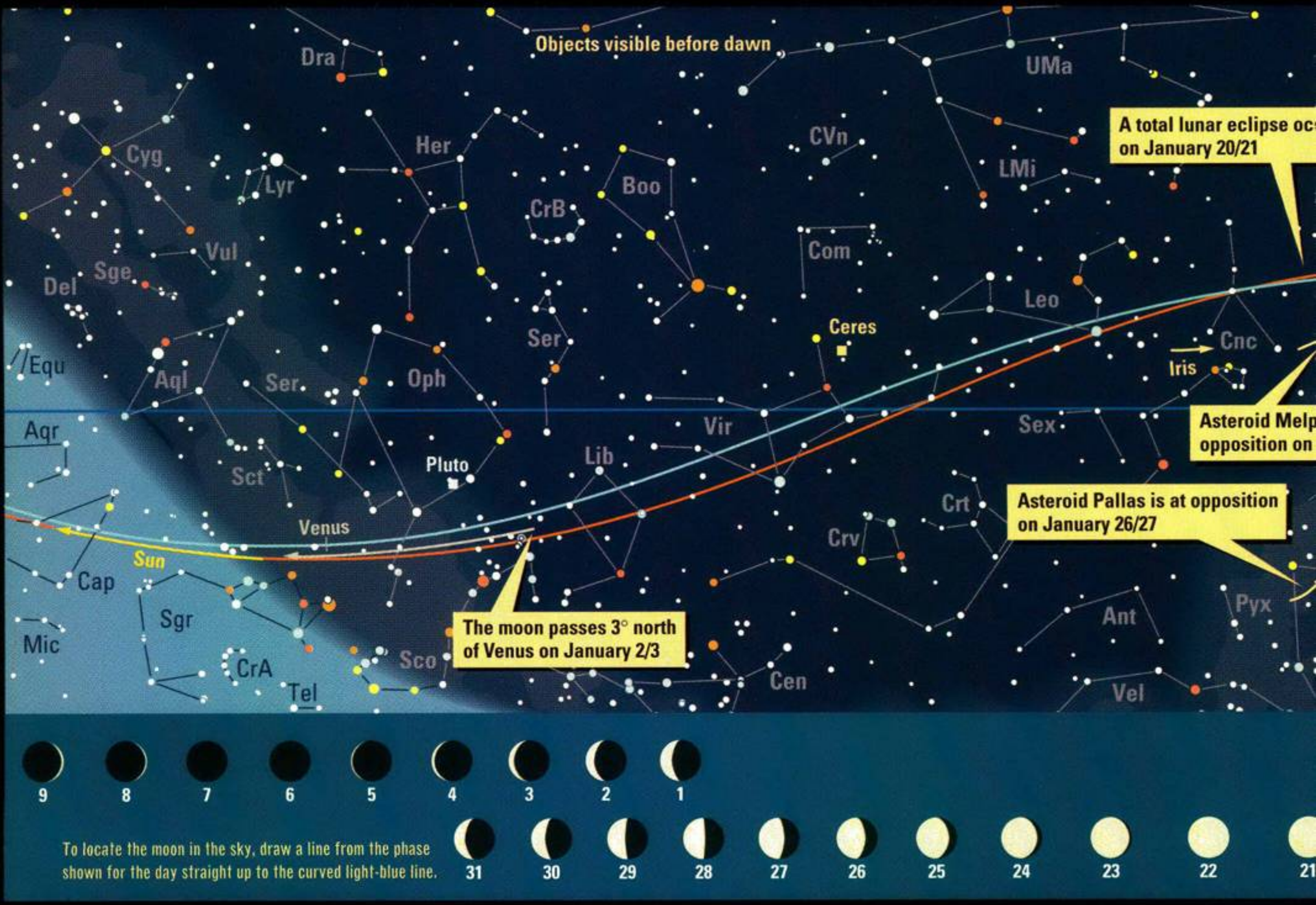
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
DRACO
URSA MINOR
URSA M
NCP
Polaris
M81
M82
CYGNUS
Deneb
CEPHEUS
LACERTA
CASSIOPEIA
CAMELOPARDALIS
NGC 869
NGC 884
Capella
AURIGA
PERSEUS
Algol
M36
M37
M38
M35
Castor
GEMINI
Pol
Lyn
M31
ANDROMEDA
TRIANGULUM
M33
PEGASUS
M15
Enif
West
Pleiades
Hyades
Aldebaran
TAURUS
M1
ORION
Betelgeuse
ARIES
PISCES
Saturn
Jupiter
Ecliptic
AQUARIUS
Mars
Mira
CETUS
M42
Rigel
ERIDANUS
LEPUS
NGC 253
SGP
SCULPTOR
FORNAX
COLUMBA
CAELUM
PHOENIX
HOROLOGIUM
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
9:00 P.M. on January 1
8:00 P.M. on January 15
7:00 P.M. on January 31

Planets are shown
at midmonth

THE PATH OF THE PLANETS


Objects visible before dawn
Dra
UMa
Cyg
Lyr
Her
CVn
LMi
Boo
CrB
Com
Vul
Sge
Del
Leo
Ceres
Ser
Cnc
Iris
Equ
Aql
Ser
Oph
Aqr
Vir
Sex
Sct
Pluto
Lib
Crt
Venus
Sun
Crv
Cap
Sgr
Pyx
Ant
Mic
CrA
Tel
Sco
Cen
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8
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2
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30
29
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21

A total lunar eclipse oc
on January 20/21

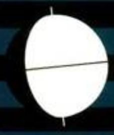
Asteroid Melp
opposition on

Asteroid Pallas is at opposition on January 26/27

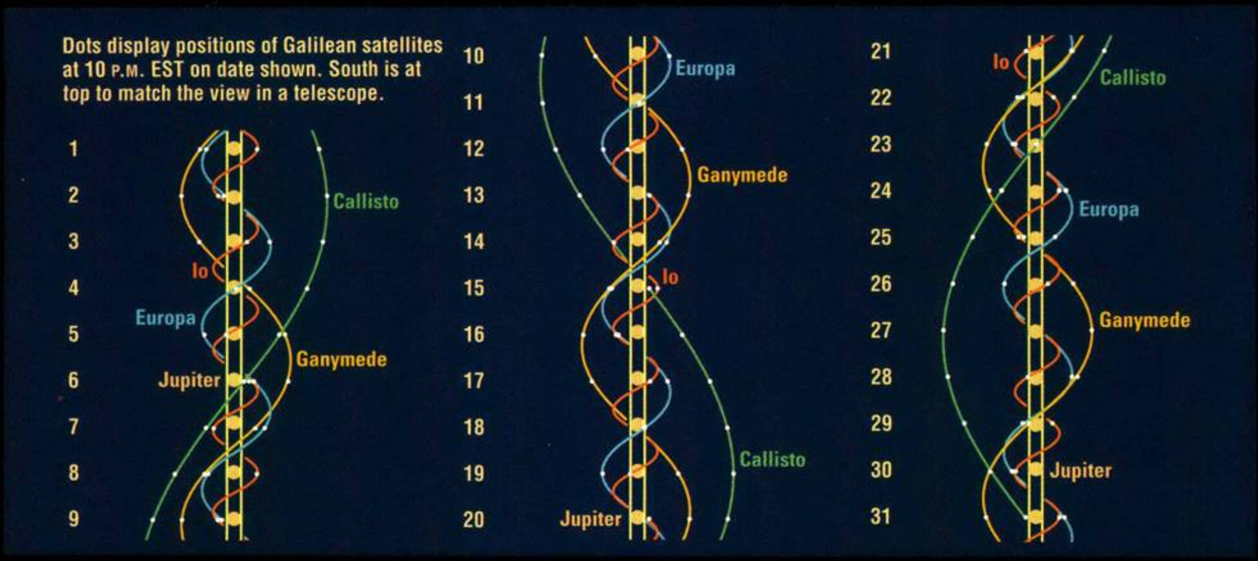
The moon passes 3° north of Venus on January 2/3

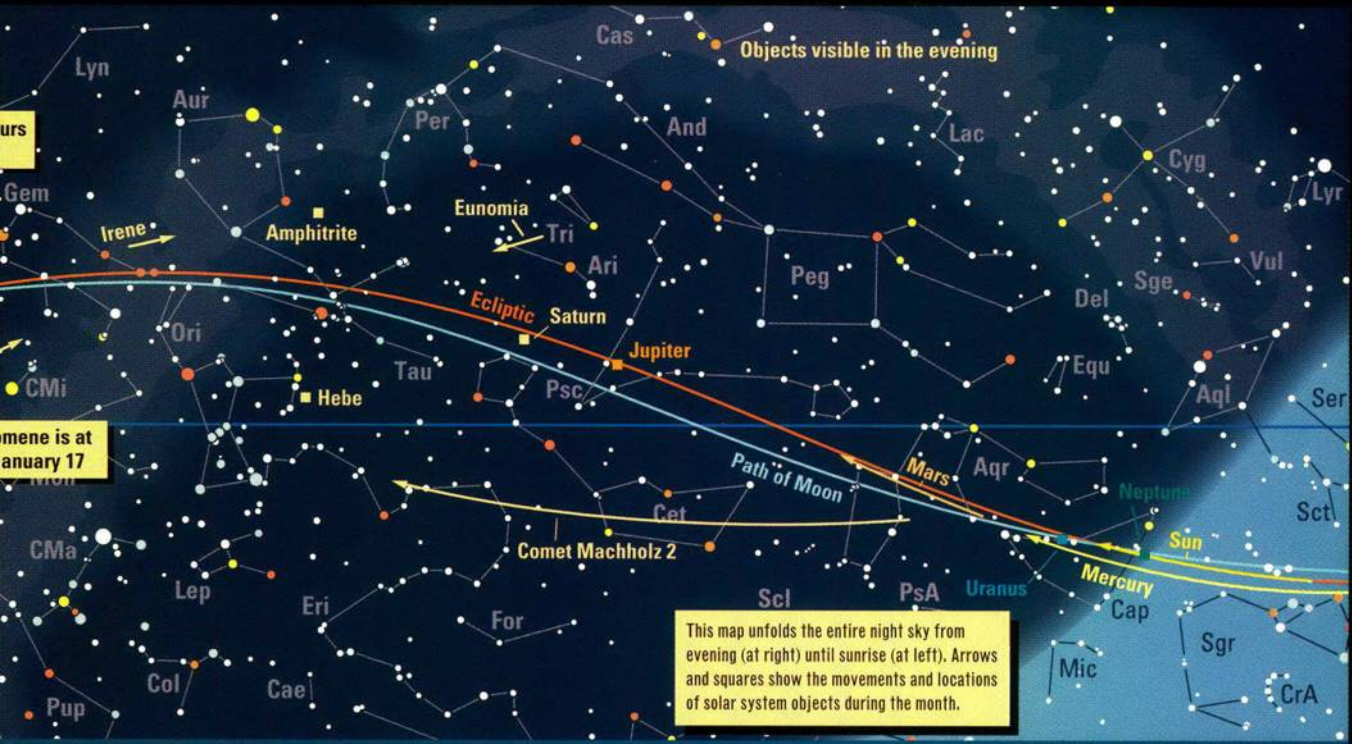
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	VENUS	MARS	JUPITER
Date	January 31	January 15	January 15	January 15
Magnitude	–1.1	–4.0	1.1	–2.4
Angular Size	5.2"	13.6"	4.9"	40.8"
Illumination	94%	80%	94%	99%
Distance (AU) from Earth	1.289	1.223	1.923	4.835
Distance (AU) from Sun	0.368	0.722	1.399	4.967
Right Ascension (2000.0)	21h35.1m	17h08.4m	22h41.6m	1h38.6m
Declination (2000.0)	–16°10'	–21°19'	–9°14'	8°58'



JUPITER'S MOONS


Dots display positions of Galilean satellites at 10 P.M. EST on date shown. South is at top to match the view in a telescope.


Cas
Objects visible in the evening
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Neptune
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Cet
Sun
CMa
Comet Machholz 2
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Lep
Scl
PsA
Uranus
Cap
Eri
For
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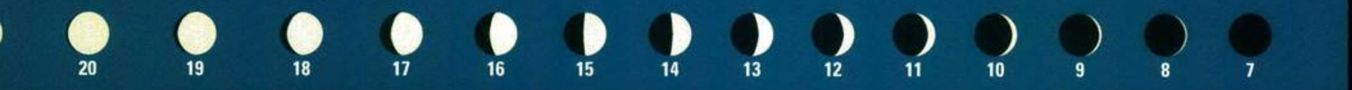
Cae
CrA
Pup

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


20
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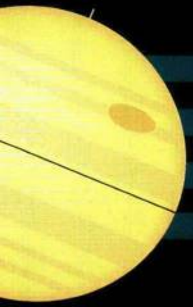
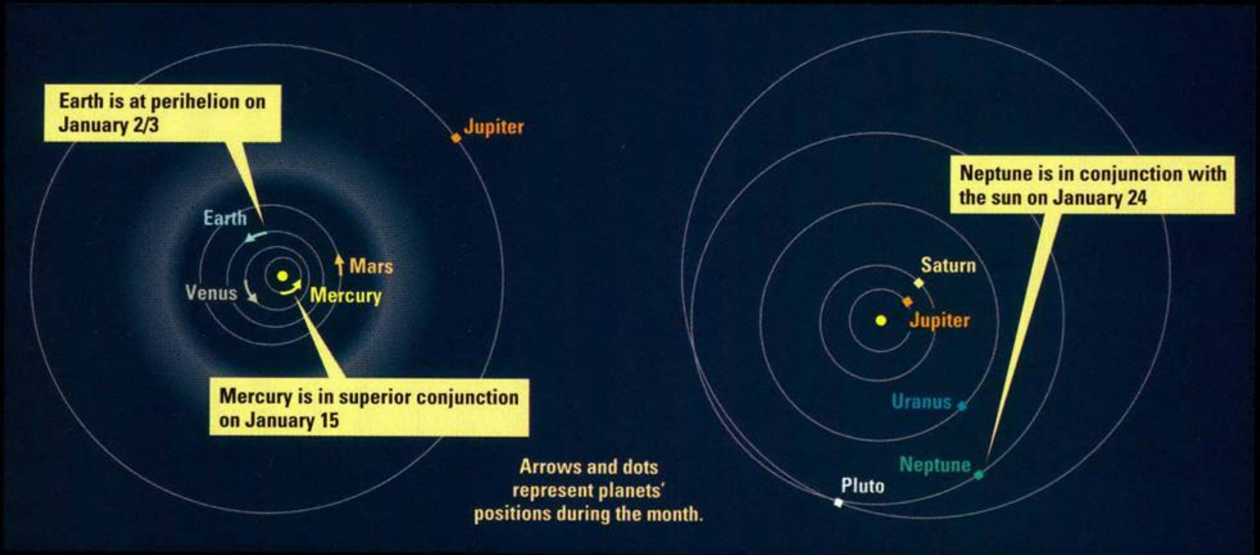


SATURN	URANUS	NEPTUNE	PLUTO
January 15	January 15	January 15	January 15
0.2	5.9	8.0	13.9
18.8"	3.4"	2.2"	0.1"
100%	100%	100%	100%
8.859	20.838	31.090	30.935
9.181	19.925	30.120	30.228
2h34.6m	21h12.8m	20h23.8m	16h47.5m
12°39'	–16°48'	–19°06'	–11°25'

THE PLANETS IN THEIR ORBITS


Jupiter
Earth
Mars
Venus
Mercury
Saturn
Jupiter
Uranus
Neptune
Pluto

Earth is at perihelion on January 2/3

Mercury is in superior conjunction on January 15

Neptune is in conjunction with the sun on January 24

Arrows and dots represent planets' positions during the month.

FIRST VIEWS: Total Eclipse of the Moon

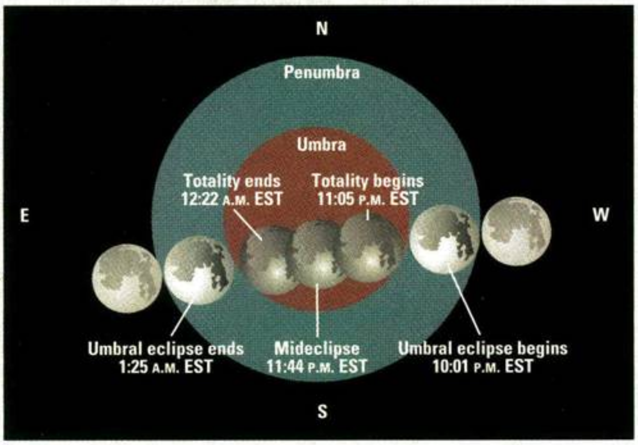
Seeing a total lunar eclipse involves much less frenzy than seeing a solar eclipse because the path of totality is huge and the event takes hours to unfold from start to finish. The moon slides through Earth's shadow on the evening of the January 20–21. If you're in Europe, the eclipse ends during the hour or two before sunrise. The last total lunar eclipse in the Americas occurred in September 1996.

Because we are watching Earth's shadow being cast onto the moon, there is no need to be concerned about eye safety. Only frostbite!

A lunar eclipse offers plenty to see. First, the moon slides into the penumbra, the fuzzy edge that shades the moon as the eclipse begins. The left side of the moon will gradually turn increasingly yellow-brown until the first dark bite of the umbra begins at 3:01 UT (10:01 P.M. EST, 7:01 P.M. PST).

Nelson Travnik

Next, use a telescope to watch the shadow gobble up craters one by one. The colors along the edge are subtle but real. At first, you won't be able to see much of anything in the shadow lands, but as totality approaches at 4:04 UT (11:04 P.M. EST, 8:04 P.M. PST), you'll find the moon bathed in a peculiar range of orangy-reds.


N
Penumbra
Umbra
Totality ends 12:22 A.M. EST
Totality begins 11:05 P.M. EST
E
W
Umbral eclipse ends 1:25 A.M. EST
Mideclipse 11:44 P.M. EST
Umbral eclipse begins 10:01 P.M. EST
S

All illustrations: *Astronomy*/ Elisabeth Rowan

You'll have 1 hour and 18 minutes to enjoy totality. Invite friends and family to share in the experience. At a minimum, you'll strike up a good argument about the 40 shades of orange produced by this grand show. The top of the moon passes barely below the darkest part of Earth's shadow, so it will display the reddest colors of all.

The moon falls completely within Earth's shadow, but the lunar surface isn't totally dark. Sunlight refracts and scatters through Earth's atmosphere, so the moon appears bathed in colors produced by sunrise twilights occurring from eastern Europe down through Africa and sunset twilights from the Aleutian Islands to Antarctica.

After totality ends at 5:22 UT (12:22 A.M. EST, 9:22 P.M. PST), the partial phase unwinds for another hour. Everything simply plays out in reverse.

If viewed from the moon, the dark earth would be surrounded by an ethereal, glowing red ring — a majestic sight for future lunar dwellers.

If the moon's orbit lay in the same plane as Earth's orbit around the sun, we would see an eclipse of the moon every month as the full moon passed through Earth's shadow. But the moon's orbit tilts almost 6° relative to the ecliptic. Usually the moon passes above or below Earth's shadow. Only when the moon is crossing a node (the intersection of its orbit with the ecliptic) and coincidentally is full does an eclipse occur.

Shortly after 9 P.M. EST, the eastern side of the moon will begin to darken as it enters the penumbral shadow (from the moon the sun would appear partially eclipsed at this stage). The action really begins an hour later, at 10:01 EST, when the moon dips into the dark shadow. It takes a full 63 minutes for the moon to become fully enveloped in the shadow, during which time the sky will slowly darken, and more and more stars will become visible. Totality lasts 78 minutes — allowing plenty of time to take a variety of pictures with a camera, either wide angle or through a telescope. Watch also through binoculars — the moon takes on a peculiar 3-D appearance during totality. Notice through the binoculars the open cluster M44, the Beehive in Cancer, just 6° to the east of the eclipsed moon. The moon leaves the umbral shadow at 1:25 A.M. Hope for clear skies.

The eclipsed moon offers a mid-month opportunity for a tour of the constellations currently visible. The brilliant winter constellations dominate — Orion stands majestically in the south at 9 P.M. local time. The sun resides on the inner section of the Orion arm — one of the spiral arms of our Galaxy. As we look toward Orion we are looking directly away from the center of our Galaxy. It's only the near proximity of the Orion arm that results in the brilliant stars in the winter sky.

Circling Orion are five constellations, each containing luminous gems. Gemini lies to Orion's northeast, housing the 1st-magnitude stars Castor and Pollux. Canis Minor lies south of Gemini and contains Procyon, the eighth brightest star in the sky and a relatively close 11 light-years distant. Sirius, the brightest star in the sky and 3 light-years closer than Procyon, leads Canis Major the Great Dog. Swinging high above Orion lies Auriga the Charioteer, home of Capella — a yellowish-colored star 70 times the luminosity of the sun. And finally, to the northwest of Orion is the famous V-shaped Hyades star cluster with the foreground 1st-magnitude red giant Aldebaran, chief star of Taurus the Bull.

These brilliant stars are the first objects to appear as the sky darkens during twilight. Twilight occurs in three stages — each allowing dimmer objects to be visible. Civil twilight begins when the sun dips 6° below the horizon, and the colors of sunset are still warming the western sky. Nautical twilight starts when the sun descends to 12° below the horizon, when the navy-blue sky drowns the more vibrant sunset hues. As the sun reaches 18° below the horizon, it marks the onset of astronomical twilight with its inky-black skies, and full nighttime officially begins. During January, astronomical twilight starts roughly 95 minutes after sunset and is latitude dependent. All the bright stars mentioned above are visible shortly after civil twilight begins, and they

Evening Escapades

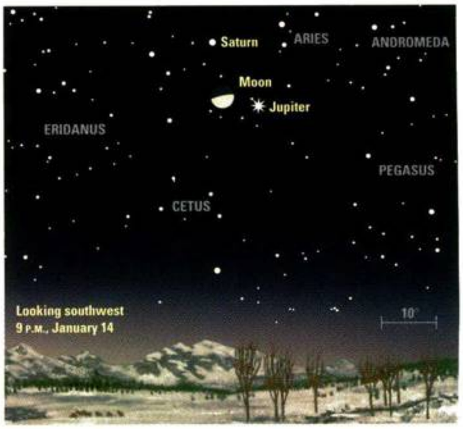
Get ready for an evening parade that will last for four months. Jupiter and Saturn slowly begin sinking toward the western twilight and, believe it or not, will catch up to the ever-fading Mars in April.

At magnitude 1, Mars does not attract great attention, but on January 10 it will be noticeable when it stands 2.5°, less than half a binocular field, to the moon's upper right. A thinner crescent can be seen the night before to the lower right.

By the 14th, the first quarter moon slides past Jupiter. Challenge yourself to find Jupiter in the daylight, with the moon acting as a guide. On the next night, Saturn shines to the moon's upper right. As each month goes by, the moon is a thinner crescent when it passes the bright pair, creating a picturesque panorama.

Due to a perspective effect, Jupiter appears to catch up to Mars. If you could ride above Earth and face the sun, the sun would appear to move east with respect to the stars. So from the ground in the Northern Hemisphere, it appears that the evening twilight slowly swallows more stars and planets each night. Because Mars orbits the sun more quickly than Jupiter or Saturn, it slides east almost fast enough to avoid the sunset's glare.

Although it appears that Jupiter and Saturn are sinking toward Mars and the horizon, the horizon and Mars are really climbing upward to overtake these two gas giants.



Looking southwest
9 P.M., January 14

Gauging the Brightness of Fireballs

If you're lucky, you've seen a blazing meteor coursing its way across the sky that left a ghostly "train." Usually it's hard to pinpoint a bright meteor's magnitude. Venus serves as an excellent reference standard because it never strays far from magnitude –4. If you look out an unobstructed eastern window this month at about 6:30 A.M., you can't miss the planet. If the fireball was brighter than Venus, you can use the moon as a benchmark.

Olin Atkinson

The crescent moon shows up on January 3, within a binocular-field view of Venus. The moon's magnitude on that morning is about –7. The first thing you'll notice is that Venus may seem brighter, and that's because its light is concentrated in one spot, not spread out like the moon's. A full moon is magnitude –12.7. A bolide this bright would easily light up the landscape.

Flares from sunlight reflecting off Iridium satellites can brighten to magnitude –8. Although from any given location bright Iridium flares occur more than once a month, the variation in their brightness and times of appearances make them pretty unreliable as comparison "stars." So you're likely stuck with comparing a jaw-dropping, blazing meteor with only your memory of the moon, Venus, or a bright satellite.

may be the only stars you can see during astronomical twilight if you live in a major metropolis.

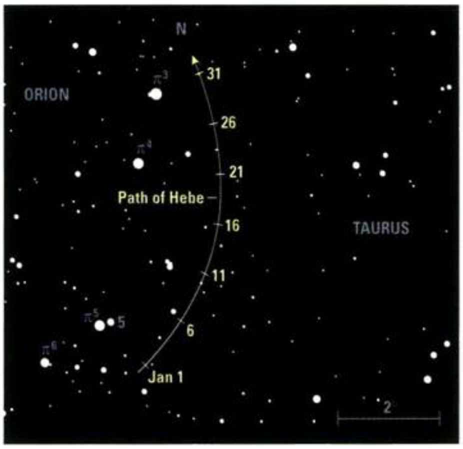
The western sky has two brilliant additions, however, and they are planets. Both can be found soon after the onset of civil twilight. At magnitude –2.5, **Jupiter** is the most brilliant object. Jupiter stands high in Pisces the Fish, a sparse region of the sky. Since Jupiter sets after midnight, most of the early evening can be set aside for fine viewing of the largest planet in our solar system, some 12 times the diameter of Earth. Only an hour of viewing through a telescope makes for enough time to notice that features in the turbulent atmosphere of Jupiter have moved, carried by the rapid rotation of the planet.

On January 7, 1610, Galileo Galilei took a new device called the telescope out into the chilly night air. He aimed it at Jupiter and became the first person to observe moons around another planet. That night he discovered Io, Europa, and Callisto, and 6 days later he found a fourth in their midst, Ganymede. These four inner, largest moons of Jupiter are now known as the Galilean satellites, in his honor.

This month, on January 7, 390 years after Galileo, you can venture out into the chilly night air and discover them for yourself. If the skies are clear on this Friday night, you can find all four of the Galilean moons spread evenly on either side of Jupiter. A decent pair of binoculars is all the visual aid needed. The satellite farthest west from Jupiter is Callisto, the second largest but outermost of the four moons. With a relatively

Tracking 6 Hebe

Hunting for space rocks constitutes a popular pastime for amateur astronomers. There's a certain sense of comfort knowing where these hurtling mountains are relative to Earth. The sixth asteroid to be discovered, 8.6-magnitude Hebe, spent last month slinking near Orion's belt. This month Hebe skirts Orion's shield stars Pi⁶ (π^6), Pi⁵ (π^5), Pi⁴ (π^4), and Pi³ (π^3).



Discovered by Karl Hencke in 1847, Hebe sports a diameter of 120 miles (190 km). The asteroid's brightness places it just within reach of a 60mm refractor from a city. Try to imagine what it was like discovering these objects visually by noting that a "star" in a field filled with faint stars had changed its place.

Try to "discover" an asteroid the old-fashioned way by making a sketch of the field, then revisiting it on a following night to see which "star" has moved. Hebe slides across a low-power field in about five nights.

If you're armed with at least a 10-inch scope under dark skies, try for NGC 1691, a faint 13th-magnitude galaxy 50' north of Pi⁵ (π^5) Orionis.

Aurora Season Heats Up

A grand display of northern lights is beyond compare. Nothing else in the sky can pulse, swoosh, and sway on such a large scale. When you're lucky, you can witness unearthly colors, too.

Aurorae glow when charged atomic particles trapped in Earth's magnetosphere cascade into the upper atmosphere more than 50 miles (80 km) up, producing photons as the particles interact with atmospheric gases. When coronal mass ejections from the sun buffet our magnetosphere in a turbulent way, a veritable storm of protons and electrons showers down. This is why northern lights are more common at the peak of the solar cycle, when the sun is most active.

A common urban myth says that aurorae are more frequent in winter. It's really an observational bias: You tend to see more in winter simply because it's dark by dinnertime and you're still awake, in contrast to the late sunsets and prolonged twilights of summer that last until you've retired for the night.

If you travel to near the Arctic Circle, past 60° north, a quiet auroral arc becomes a nightly feature of the sky. It's where Earth's magnetic field lines increasingly converge toward the poles. To see an aurora from the southern states, an incredibly active storm must occur. When this happens, observers farther north witness the most awesome light show on the planet. Instead of faded pastels of pink, purple, and green, the colors are as saturated as those from a box of crayons.

Jay Brausch

Several websites forecast the likelihood of aurorae. Try http://www.spaceweather.com to get started.

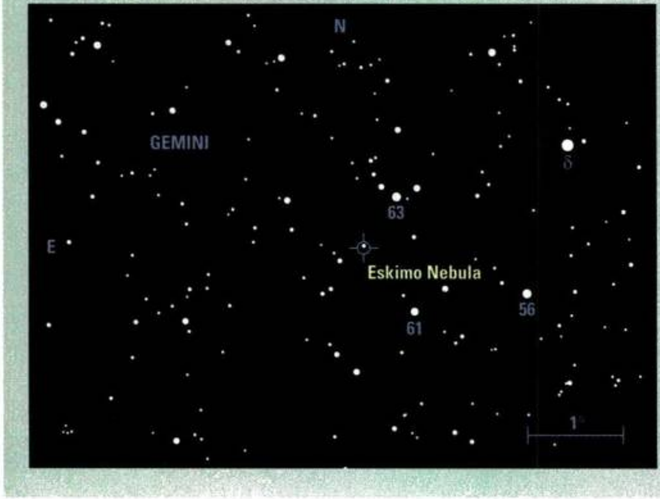
OBSERVER'S CHALLENGE: The Eskimo Nebula

On icy winter nights, the Eskimo Nebula makes for a perfect target. It's bright enough to pierce a city's veil of light pollution; it's big enough for an inexperienced eye to see; and its central star is obvious.

The Eskimo Nebula (NGC 2392) is called a planetary nebula because 17th- and 18th-century observers believed that these little gas puffs resembled faint, bloated cousins of Uranus. Two hundred years ago, the spectroscope of British chemist William Huggins revealed that the Eskimo's light comes from a fluorescing gas and not from a group of faint, unresolved stars.

To locate the Eskimo, use a little diamond-shaped group of stars in southern Gemini (see map). The nebula is just recognizable at 50x, but 150x or more is better: A uniform, gray disk of light encircles a relatively bright star dead in the center. Watch the nebula wink off and on as you shift your vision on and off the central star. This experiment proves that glancing to the side with averted vision makes deep-sky objects easier to see.

George Valachovic



The name Eskimo came from the nebula's appearance in photographs taken with large telescopes. Even Lord Rosse, with his 72-inch speculum mirror, had a tough time seeing detail worthy of expounding on, and he was sometimes accused of exaggerating. Some gray splotches on the main disk appear a bit like an open "mouth" and "eyes," while striations on the outer disk can only bring to mind the fur-lined hood of a "parka." When observing this nebula during these frosty winter months, it's hard to conjure up anything else.

low albedo (reflectivity), it's the faintest Galilean moon.

Between Callisto and Jupiter floats Io, the third largest and innermost of the four moons. When the Voyager spacecraft flew by Io in 1979, it returned pictures to Earth of a volcanically active surface, where sulfur spewed across the land, creating yellowish deposits.

Moving to the east side of Jupiter you'll find Ganymede, the largest moon in the entire solar system. Due to its size and icy-covered face, it has a high albedo and therefore should be easy to pick up in binoculars.

The last of the Galilean satellites, Europa, ranks as the fourth largest and can be found the farthest east on the night of January 7. Europa's fame in recent years comes from an important finding that it has an icy-smooth surface, with hardly any craters. Some researchers believe that a subsurface ocean exists on Europa, heated from below by internal activity.

When you tire of your Galilean gazing, turn to Jupiter's equally worthy neighbor. **Saturn** sets an hour later than Jupiter and shines at magnitude 0.3 by month's end. It reaches a stationary point among the stars of Aries on January 13 — a point that simply represents the fact that Earth now moves directly away from Saturn. Its direct eastward motion against the background stars will resume within a few days. As we loop around the farside of the sun, Saturn will appear to sink into the evening twilight — a slow event that takes a few months to complete.

The evening sky also houses **Mars**, now shining at magnitude 1.1. During January, Mars traverses the stars of Aquarius the Water-bearer and gets passed by a young crescent moon on January 10, when Mars lies 3° northwest of the 4-day-old crescent. Mars sets shortly after 9 P.M. local time. Compared to its appearance last spring, the Red Planet is disappointing now through telescopes, its scant 5" diameter hiding any detail. But outstanding detail should be pouring in to us from Mars Polar Lander, which is scheduled to touchdown on December 3, 1999.

Another fine red object makes its presence felt during these gray winter evenings. Mira (Omicron [o] Ceti) was originally believed to be a nova when it was discovered. But this star, with a diameter 300 times that of the sun, was correctly identified as periodic in 1638 and has since become the prototype for variable stars. Mira passed its maximum brilliance in December. Try to determine its magnitude. Perhaps it's now shining at 3rd magnitude as it begins to fade slightly. You can follow the dimming by observing Mira in Cetus the Whale every couple of weeks and comparing its brilliance to neighboring stars. Mira floats 6° southwest of the magnitude 4.1 star Delta (δ) Ceti. To acquire useful results you should get an accurate magnitude of each comparison star using guide charts obtainable from the American Association of Variable Star Observers (AAVSO; http://www.aavso.org).

After midnight, winter stars move to the western sky and stars of spring enter the eastern sky. By 5 A.M. in early January, the dazzling magnitude –4.1 **Venus** can be seen rising in the southeast as the dawn's light begins to sprinkle its rays upon the horizon. Check out the lovely waning crescent moon positioned 5° east of Venus and due north of Antares in Scorpius early in the morning of January 3. This is also the best morning to watch for the Quadrantid meteor shower (see "Prime Viewing for the Quadrantids," page 77).

Two nonvisible, but nonetheless interesting, events in January include **Mercury** reaching superior conjunction on January 16, and therefore it is not visible all month. It moves into the evening sky and will become visible in early February. Last but not least, **Earth** reaches perihelion on January 3 at midnight Eastern Standard Time. ▣

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

The Hyades and the Pleiades

Only bright star clusters have proper names, and two of the brightest appear side by side in the winter sky, easily visible to the naked eye except from the most light-polluted cities.

First-timers will surely gasp when they see the Pleiades (M45, or the Seven Sisters) through binoculars. The compact dipper shape is mimicked in the Subaru logo, but most mistake the Seven Sisters (not surprisingly) for the Little Dipper, which is actually many times the size of the Pleiades.

The Pleiades were born after the dinosaurs were wiped out, and most of the hot, bright stars will burn out long before the sun begins to show signs of age. The Hipparcos satellite has refined the distance to the Pleiades to 375 light-years, down from 410. The group itself spans 7 light-years across.

By contrast, the V-shaped Hyades cluster is much closer, about 130 light-years away. Because it's nearer, it spans a larger area of sky, almost spilling out of the field of a standard pair of binoculars. We've known for a long time that the bright, ruddy star Aldebaran is much closer to Earth than the others. A few years ago Hipparcos nailed it down to a distance of 65 light-years.

Randal P. Dean

When the moon passes in front of the Hyades, we are treated to a whole series of stars disappearing over the course of a couple hours. We're in the middle of an occultation series of the Hyades. The moon gets a chance to move in front of the Pleiades too. The next series of Pleiades occultations begins in 2006.

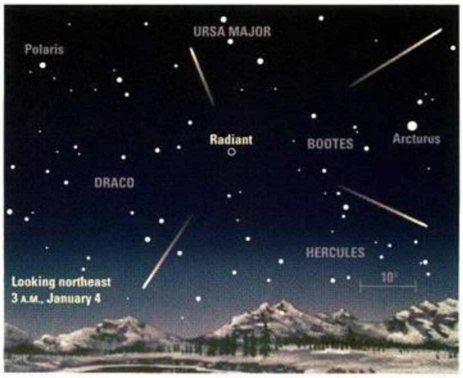
Prime Viewing for the Quadrantids

The Quadrantid meteor shower should be high on everyone's list because the viewing conditions are fairly optimal this year. Counts vary from year to year, ranging from 50 per hour to over 150 under dark, country skies.

The highest rates occur for only a few hours. If you're on the other side of the planet during the peak, you'll only see a few by the time Earth rotates you into the stream of old comet dust.

The heaviest activity arrives on the night of January 3–4 at 6 UT (1 A.M. EST, 10 P.M. PST), favoring eastern North American observers. The moon is almost new, so there's no interference like last year's full moon.

Another factor to contend with in January is the highly variable weather. Remember to bring warm drinks and bundle up more than you think necessary.



The modestly speedy meteors (25 miles [40 km] per second) that vaporize in Earth's atmosphere appear to come from northern Boötes, near the tail of the Big Dipper. Back in the 18th century, this area was called Quadrans Muralis, hence the name Quadrantid meteors.

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Perseus & Taurus

Big, bright star clusters and wispy nebulae populate the constellations of the Hero and the Bull.

by **Tom Polakis**

With frigid arctic air now covering a good portion of the northern latitudes, abandoning the warmth of indoors for a night of stargazing is the last thing many people have on their minds. That's their loss. The cold temperatures often bring with them crystal-clear skies that will warm the heart of any backyard observer. So grab a telescope, don that parka, and fill a thermos with your favorite hot beverage — it's time to get out and see some of winter's many celestial wonders.

January evenings find the band of the Milky Way arching high across the sky and cutting through two venerable constellations: Perseus and Taurus. The winter Milky Way has a much different character than the more familiar regions of summer. Here we look in the opposite direction from the center of our Galaxy, toward the nearby Perseus spiral arm. Although the two constellations contain perhaps the palest stretch of the Milky Way, the region nevertheless abounds with emission nebulae and some of the best and brightest star clusters in the sky.

Two brilliant and easily recognizable star clusters — the Pleiades and Hyades — form the centerpiece of Taurus the Bull. The V-shaped Hyades represents the face of the bull, with the fiery eye depicted by the 1st-magnitude foreground star Aldebaran (Alpha [α] Tauri). The Pleiades, which looks like a small dipper to the naked eye, stands at the bull's shoulder. Although conspicuous without optical aid, these clusters come alive in binoculars or a small telescope, and we'll return to them later.

For a constellation that contains a dozen stars brighter than magnitude 4.0, Perseus the Hero is surprisingly difficult to trace. Start with a trio of bright stars — Alpha, Beta (β), and Delta (δ) Persei — that forms a skinny isosceles triangle near the constellation's center and from there follow the pattern to the north and south.

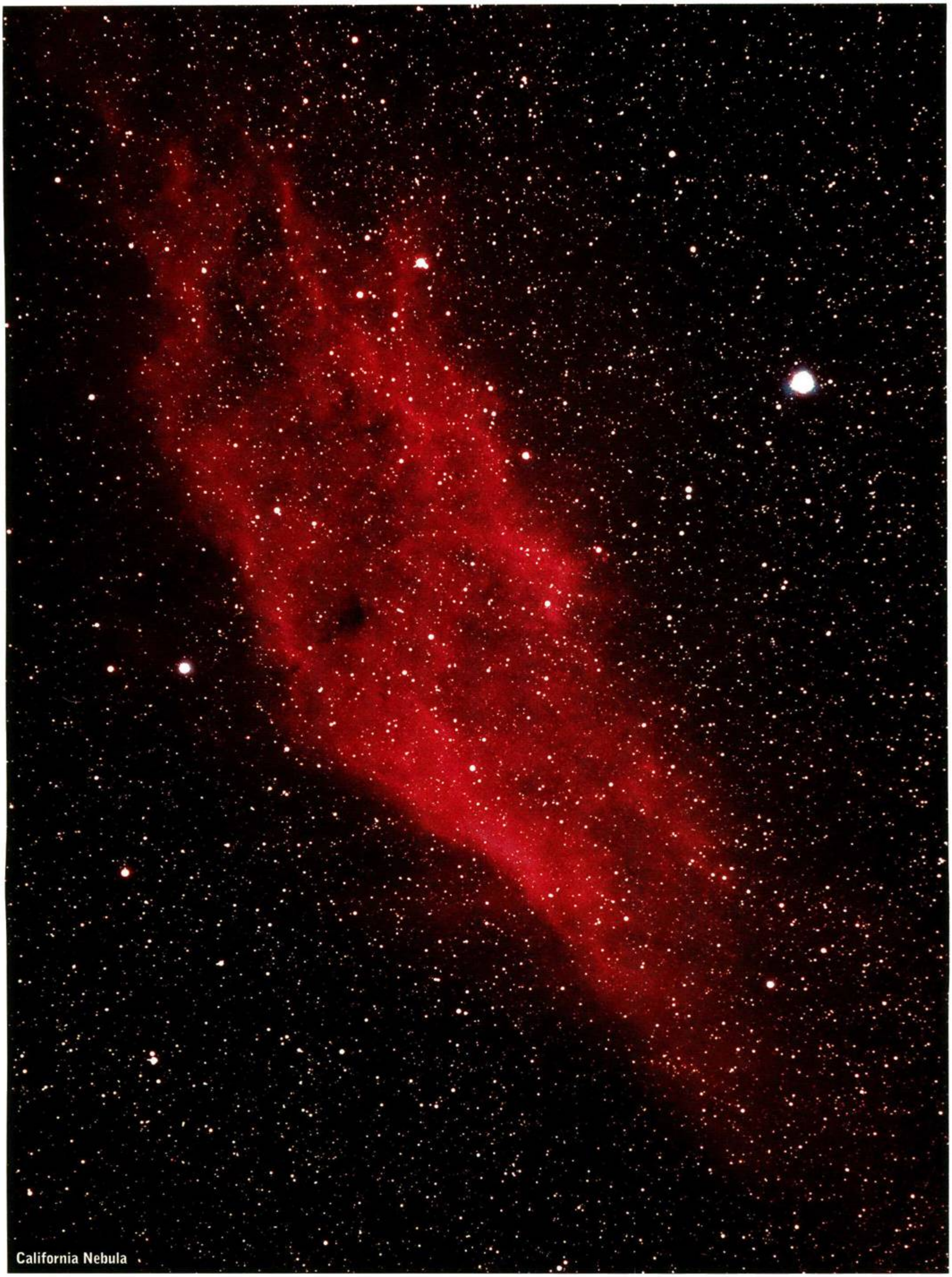
The star at the vertex of this triangle, Beta, lies nearly 100 light-years away and ranks as one of the most famous in the sky. Also known as **Algol**, the Demon Star, this object

Jack Newton

NGC 1245

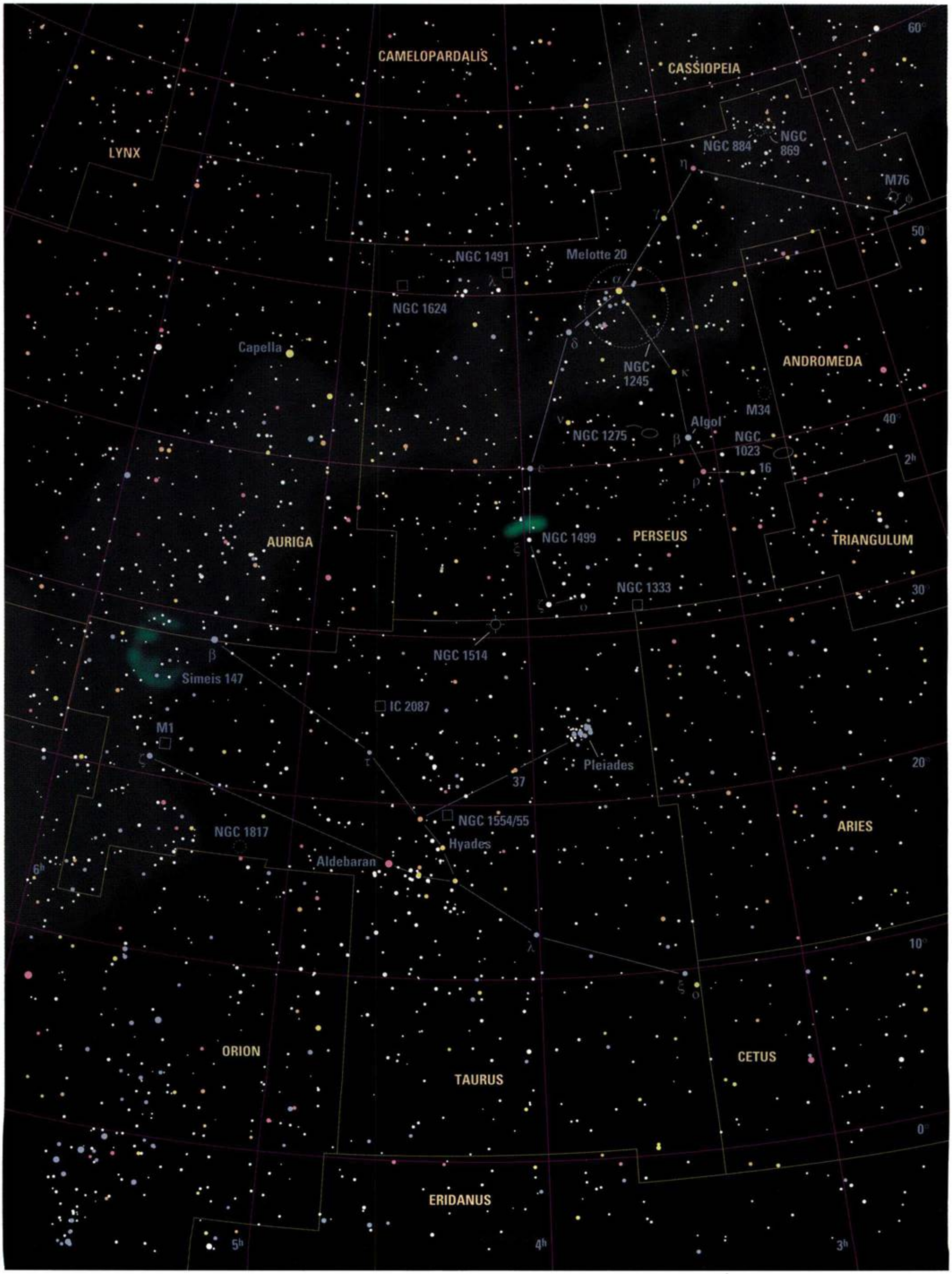
M34

Robert Provin



California Nebula

George Greaney; artwork at left from *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.


CAMELOPARDALIS
CASSIOPEIA
60°
LYNX
NGC 884
NGC 869
η
M76
φ
γ
50°
NGC 1491
λ
Melotte 20
α
NGC 1624
Capella
δ
NGC 1245
κ
ANDROMEDA
M34
ν
NGC 1275
Algol
β
NGC 1023
40°
ε
ρ
16
2h
NGC 1499
ξ
PERSEUS
TRIANGULUM
AURIGA
NGC 1333
ζ
ο
30°
NGC 1514
β
Simeis 147
IC 2087
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37
20°
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ARIES
NGC 1817
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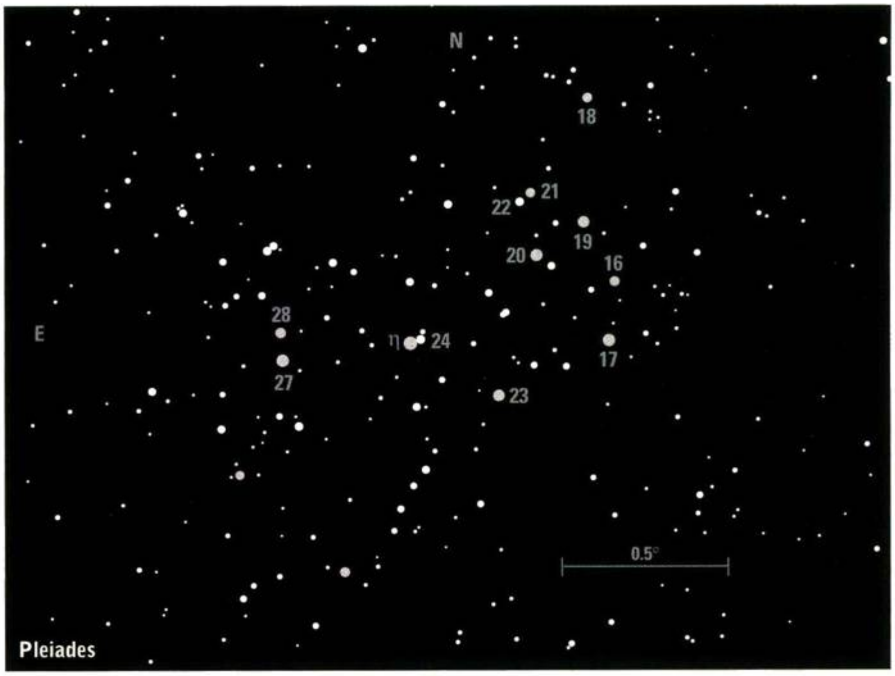
ORION
CETUS
TAURUS
0°
ERIDANUS
5h
4h
3h

normally shines at magnitude 2.1. Yet every 2 days, 20 hours, and 49 minutes, Algol dims by 70 percent, to magnitude 3.4. This dip in brightness occurs when a fainter, unseen star in orbit around Algol passes in front of the brighter star and blocks some of its light. Each eclipse lasts approximately 10 hours. The first of many thousands of such eclipsing binary stars to be discovered, Algol remains the easiest to observe. Most of the time it appears nearly as bright as Alpha Persei, but keep an eye on it and you may catch it dim below the level of Delta.

The first stop on our telescopic tour of these constellations sits in far western Perseus, near its border with Cassiopeia and Andromeda. The **Little Dumbbell Nebula** (M76, NGC 650/51) lies 1° north of the 4th-magnitude star Phi (ϕ) Persei. This planetary nebula glows softly at magnitude 10.1, giving it the distinction of being the faintest object in Charles Messier's catalog of 107 deep-sky objects. Don't let that fool you, however, because M76 appears as a fairly bright, elongated disk measuring about 1' across. It also contains plenty of detail that shows up nicely at higher magnifications. An 8-inch telescope reveals the two lobes that gave the nebula its name, with the southwestern patch appearing a little brighter. A 16-inch scope brings out a faint strand extending west from the northeastern lobe. You might even catch a hint of the large, diffuse halo that surrounds the entire inner region. The Little Dumbbell Nebula lies roughly 4,000 light-years from Earth.

Despite their name, planetary nebulae have nothing to do with planets — the term arose because early observers saw a superficial resemblance between them and the planets Uranus and Neptune. Planetaries actually represent the final fate of low-mass stars like the sun. Once these stars exhaust their nuclear fuel, they gently puff off their gaseous outer layers, forming intricate shapes.

Eight degrees northeast of M76 lies a real star-party favorite, the **Double Cluster** (NGC 869 and NGC 884). This pair of colorful star clusters fits comfortably in a 1° field. Although any wide-angle instrument shows this magnificent region well, the best views probably come with small, sharp refractors that faithfully present the



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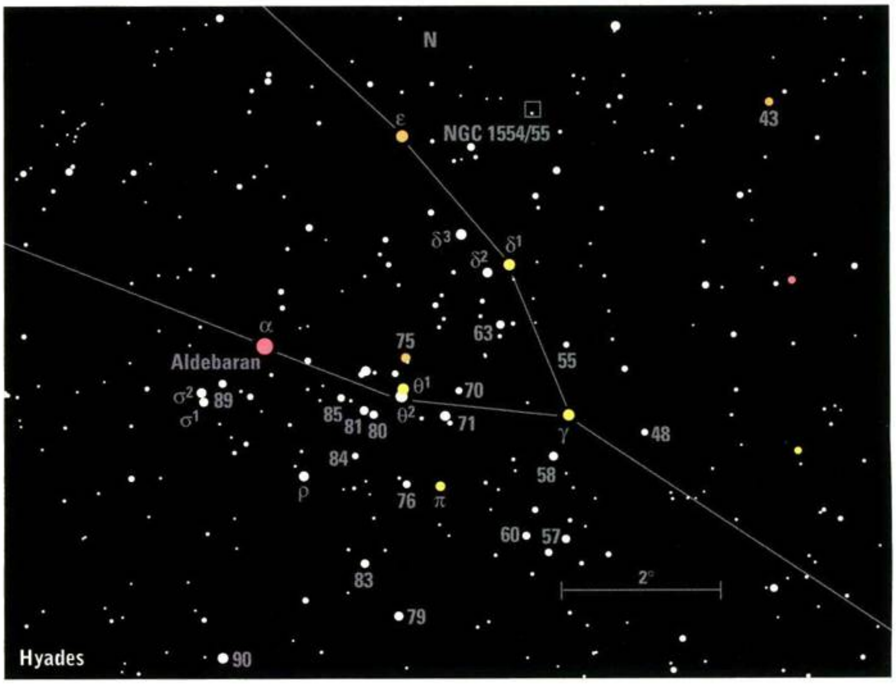
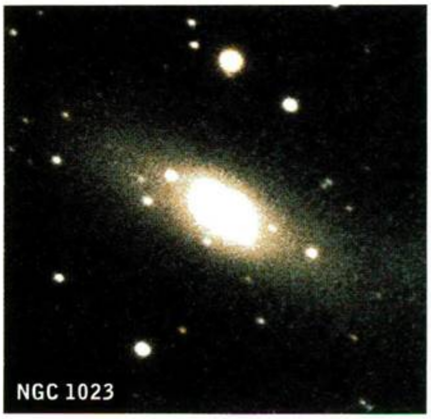




Bill Iburg

Kim Zussman

wide variety of star colors and brightnesses. NGC 869 is the richer of the two clusters, containing some 30 9th- and 10th-magnitude stars packed into a diameter of 10'. Roughly 200 stars call this cluster home. Although it appears less concentrated than its neighbor, NGC 884 actually holds more bright stars, with the densest grouping on the southwestern edge. Both NGC 869 and 884 lie between 7,000 and 8,000 light-years away.

Another brilliant stellar group lies in the heart of Perseus. The **Alpha Persei Association** (Melotte 20) is a large, scattered group of bright stars that appears obvious to the naked eye even though it lies 600 light-years away in the rich starfields along the galactic plane. For the best view, try binoculars or a rich-field telescope. At a magnification of 20x or less, you can expect to see some 50 bright stars — most prominently Alpha and Psi (ψ) Persei — mainly to the south and east of Alpha. All told, more than 100 young stars brighter than magnitude 12 spread across the association's 3° girth.

Next scan 7° east of Alpha to pick up Lambda (λ) Persei, then sweep 1° northwest of that 4th-magnitude star to find the bright emission nebula **NGC 1491**. A 10-inch telescope equipped with a nebula filter clearly shows its bright fan shape. The nebula appears brightest on the western edge and fades gradually toward the more diffuse eastern side. A 16-inch scope reveals striations that extend away from the nebula's southern tip. Don't expect to see a nebula that even approaches the cataloged size of 25'; in the eyepiece it scarcely spans 4'.

Another 5° east of Lambda Persei, tucked in the far northeastern corner of Perseus, resides an intriguing cluster surrounded by a nebula. **NGC 1624** appears only 3' across, but that translates into a diameter of 17 light-years at its distance of nearly 20,000 light-years. The cluster holds a dozen faint stars that nevertheless appear distinctly as a cluster because they're tightly packed. A uniform, gauzy glow surrounding the stars suggests dew on the optics.

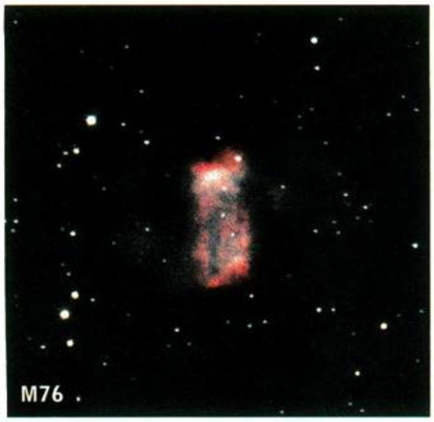
A far richer cluster lies just 3° southwest of Alpha Persei. You can spot **NGC 1245** in a finderscope, while an 8-inch scope shows 60 stars arranged in pretty arcs surrounding a pair of nearly starless voids. Although high magnifications raise the star count, they diminish the overall splendor of this excellent cluster. An 8th-magnitude star gleams at the cluster's southern edge.

Pan 7° southwest of NGC 1245 and you'll come to another of Perseus's naked-eye open clusters, **M34** (NGC 1039). Even the most modest telescope shows the beauty of this Messier object, wherein 10 stars brighter than 9th magnitude stand out. A 6-inch scope reveals 40 members between 8th and 12th magnitude, and doubling the aperture doubles the star count. At medium powers, look for chains of faint stars crisscrossing the field. The light from M34's stars has traveled 1,500 years to reach our eyes.

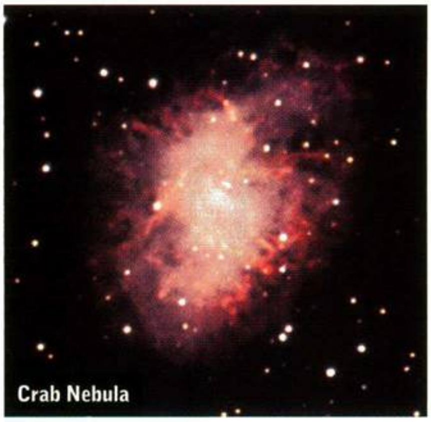
A nice change of pace from the clusters and nebulae lies just 4° south of M34. The lenticular (lens-shaped)

Pleiades

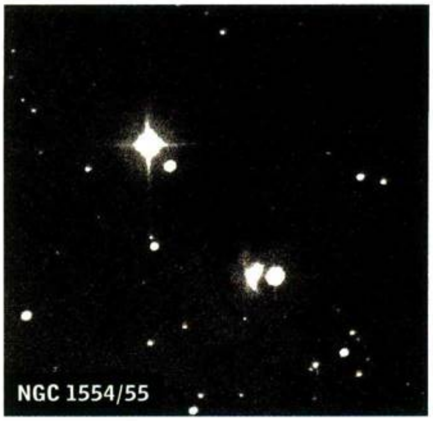
Tony and Daphne Hallas


M76

Jack Marling


Crab Nebula

Bill and Sally Fletcher


NGC 1554/55

Martin Germano

galaxy **NGC 1023** appears quite bright, especially at its center, and three times as long as it is wide. Magnifications of more than 200x show the nearly stellar nucleus. You may also see NGC 1023A, an irregular galaxy once thought to be an asymmetrical spiral arm, which appears embedded in the eastern end of NGC 1023's halo. Located some 30 million light-years away, NGC 1023 belongs to a galaxy group that includes NGC 891, NGC 925, and NGC 1003.

Sweep 2° east of Algol and you'll head far deeper into space. The galaxy **NGC 1275** lies at the heart of the Perseus Galaxy Cluster (Abell 426) and shines across 270 million light-years. Classified as a Seyfert galaxy, NGC 1275 emits huge amounts of radiation from its core. It ranks as the brightest radio source in the constellation, earning a designation of Perseus A.

In a telescope, NGC 1275 appears bright, small, and nearly circular. A nearly identical galaxy, NGC 1272, lies just 5' to the west. Most of the galaxies visible in the Perseus Cluster lie to the south and west of NGC 1275 — an obscuring cloud of the Milky Way blocks the view to the northeast. A 10-inch telescope reveals a dozen galaxies, most just barely nonstellar, in a field of view 1° across.

The small size and great distance of the galaxies in Abell 426 stand in stark contrast to the large, nearby emission

Deep-Sky Objects in Perseus and Taurus

Object	R. A. (2000.0)	Dec.	Mag.	Size/Per.	Type	Notes
M76	1h42.4m	51°34'	10.1	65"	PN	Little Dumbbell Nebula
NGC 869	2h19.0m	57°09'	5.3	29'	OC	Half of Double Cluster
NGC 884	2h22.4m	57°07'	6.1	29'	OC	Half of Double Cluster
NGC 1023	2h40.4m	39°04'	9.3	8.6' by 4.2'	Gal	SB(rs)0
M34	2h42.0m	42°47'	5.2	35'	OC	
Beta Persei	3h08.2m	40°57'	2.1–3.4	2.867 days	Var	Algol
NGC 1245	3h14.7m	47°15'	8.4	10'	OC	
NGC 1275	3h19.8m	41°31'	11.9	3.2' by 2.3'	Gal	In Abell 426
Melotte 20	3h22.0m	49°00'	1.2	185'	OC	Alpha Persei Association
NGC 1333	3h29.3m	31°25'	—	6' by 3'	BN	
M45	3h47.0m	24°07'	1.2	110'	OC	Pleiades
NGC 1499	4h00.7m	36°37'	—	160' by 40'	BN	California Nebula
NGC 1491	4h03.4m	51°19'	—	25' by 25'	BN	
NGC 1514	4h09.2m	30°47'	10.9	114"	PN	
NGC 1554/55	4h21.8m	19°32'	—	1'	BN	Hind's Variable Nebula
Hyades	4h27.0m	16°00'	0.5	330'	OC	
IC 2087	4h40.0m	25°44'	—	4' by 4'	BN	
NGC 1624	4h40.4m	50°27'	—	5' by 5'	BN	
NGC 1817	5h12.1m	16°42'	7.7	15'	OC	
M1	5h34.5m	22°01'	—	6' by 4'	BN	Crab Nebula
Simeis 147	5h39.1m	28°00'	—	200' by 180'	BN	Supernova remnant

Object: Designation in Messier, NGC, or other catalog. **R.A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Per.:** Size in arcminutes or arcseconds, or period in days. **Notes:** Hubble type for galaxies.

Double Cluster

Jerry Lodriguss

nebula dubbed the **California Nebula** (NGC 1499). As wide as the full moon and four times as long, the California ranks as one of the sky's larger emission nebulae. It's even bright enough to be glimpsed with the naked eye from a very dark site. Use a nebula filter and look just north of 4th-magnitude Xi (ξ) Persei, the extremely hot star that excites the gas in the nebula and causes it to glow. Looking through a filtered 4-inch refractor, you should barely make out the full size and shape of the nebula, which bears a faint resemblance to its namesake state. The California is one of the few nebulae whose visibility improves with a Hydrogen-beta filter; an Oxygen III filter, on the other hand, hinders the view. To best see the nebula, sweep the telescope's field of view across its surface.

In southernmost Perseus, right where its border intersects those of Taurus and Aries, lies the reflection nebula **NGC 1333**. The molecular cloud surrounding the nebula has been giving birth to stars over the past 100,000 years, making them similar in age to the Trapezium stars in the Orion Nebula. In an 8-inch telescope, NGC 1333 shows up easily as a clumpy haze, 7' by 4' across. It appears brightest at the northeastern end, where the 10th-magnitude star that illuminates the nebula resides. A large telescope reveals a brighter strip along the southern end. You should also see several dark obscuring clouds — made apparent where they create nearly starless fields — in the nebula's immediate vicinity.

Nine degrees east of NGC 1333 and just over the border into Taurus lies a fine planetary nebula, **NGC 1514.** Viewing through a UHC filter at 150x, the planetary appears as a thick ring with a slightly darker center. Although the edges look quite diffuse, brighter knots show up on the northwestern and southeastern sides. In 1790, the great English observer William Herschel described NGC 1514 as "a star involved in a shining fluid of a nature totally unknown to us." The 9th-magnitude star Herschel saw dead center in the ring is not the one that provides the energy for the nebula to glow, however — that honor goes to the star's very hot white-dwarf companion.

If the night air is so cold that you can't stand being out for more than a few minutes, one object still deserves your attention. The **Pleiades** (M45) earns its distinction as the most recognized star cluster and one of the finest deep-sky objects in the sky. Situated only 400 light-years away, M45 appears large: the crowded inner regions span more than a degree and members have been found as far as 5° from the center. At magnitude 1.2, it also ranks as the brightest object in the Messier catalog.

The Pleiades provides a good test of your eyesight. Some people see only a fuzzy patch of light with the naked eye, though most can make out the six brightest stars that form the dipper shape. And a few eagle-eyed people observing on dark nights have reported seeing a dozen or more stars in the cluster. Every form of optical aid offers something new to the backyard observer. Through binoculars, the cluster comes into its own, with dozens of bright stars swimming in the field of view. Look for a gorgeous chain of eight stars that runs south from the dipper's bowl. A small scope that provides a 3° field probably shows the entire cluster best (high magnifications simply cut out too many stars).

For more of a challenge, search for the Merope Nebula, a tenuous reflection nebula that permeates the cluster.

The Bull

"Ere the heels of the flying Capricorn
Have touched the western mountain's darkening rim,
I mark, stern Taurus, through the twilight gray,
The glinting of thy horn,
And sullen front, uprising large and dim,
Bent to the starry Hunter's sword at bay."
Hymn to Taurus
— James Bayard Taylor (1825–1878)

Taurus the Bull is a unique constellation in that two open clusters mark its form. At one end, the V-shaped Hyades is the framework of the Bull's head, while the Pleiades marks his shoulder at the opposite end.

In classical mythology, the Hyades signifies the sisters of Hyas who died of grief over the death of their brother. Members of the Pleiades are also said to be part of this family, but they died of grief at the death of the Hyades.

Native American legends surrounding these clusters are more whimsical. The Yokut and Monache people of the San Joaquin Valley tell one story. The Pleiades symbolized six young wives and the Hyades their husbands. The Pleiades didn't much like their husbands, so one day while out foraging they ate wild onions and got "skunk" breath. That evening when the Pleiades returned home, their husbands — repulsed by their bad breath — threw them out. The Pleiades climbed to a mountaintop, laid out their rope talismans, and began to chant. They called to the spirits for help and were soon whisked into the sky. Their lonely husbands soon followed. Today we see them chasing behind their wives, never to catch them.

The Bull figures prominently in Greek and Roman mythology, in particular the legends of Crete. Myths surround Pasiphae and the bull sent by Poseidon, Europa and the white bull that carried her off, Theseus and the Minotaur, and Io, attesting to the Bull's significance.

Europa was the daughter of the king of Tyre, and Zeus fell in love with her. To win her affection, Zeus came to Europa in the form of a beautiful, white bull. Enchanted by the bull's gentle nature, Europa soon felt safe enough to climb on its back. Seizing the opportunity, Zeus quickly carried her away. — *Andrea Gianopoulos*

As little as 3 inches of aperture will show the brightest area, which lies south of the star Merope (23 Tauri) and is designated NGC 1435. Optics with high contrast really shine in bringing out the faint wisps that surround the brightest members. The nebulosity arises from interstellar dust — which reflects the light of the Pleiades' blue-white stars — belonging to a cloud that just happens to be passing through the cluster.

Despite being closer, larger, and brighter than the Pleiades, the **Hyades** doesn't look as spectacular: The bright stars just spread out too much. With a diameter of more than 5°, the V-shaped Hyades appears as a cluster only to the naked eye or in binoculars, which show the region best. Save your telescope for close-up views of the many fine double stars in the cluster. The Hyades lies only 150 light-years away, while Aldebaran, the bright orangish star that masquerades as a member, resides just 65 light-years from Earth.

A far more challenging object lies a little north of the Hyades. **NGC 1554/55**, also known as Hind's Variable Nebula, appears as a faint wisp of nebulosity near the variable star T Tauri. You'll probably need a 16-inch or larger telescope to glimpse the nebula, which lies more than 450 light-years from Earth. A decade ago, the object was visible in smaller scopes.

Sweep 7° northeast of Hind's Variable Nebula and you'll come across the reflection nebula **IC 2087**. In a 13-inch telescope, it appears as a uniform circular haze about 5' across. More interesting than the nebula, however, is the surrounding starfield, which seems nearly nonexistent. The Taurus dark cloud obscures entire 1° fields in this region, only to be bordered by magnificently star-studded areas.

A well-defined open cluster lies just north of the Orion border. **NGC 1817** contains 60 or so stars within its 15' diameter. A striking chain of stars delineates the cluster's western edge.

The best known supernova remnant in the sky dwells in eastern Taurus, just 1° northwest of 3rd-magnitude Zeta (ζ) Tauri. The **Crab Nebula** (M1) began life when a massive star reached the end of its life. The star exploded in a supernova seen on Earth in the year 1054, when it shone as brightly as Venus despite lying 6,500 light-years away. Photographs spanning only a few decades show the filaments expanding from the location of that progenitor star, where a rapidly spinning pulsar now resides. Views of M1 through a small telescope can prove disappointing, showing a nearly uniform illumination with notches cut out of the sides. A 20-inch scope at a dark site begins to reveal the filaments that gave the nebula its name.

Six degrees north of M1 lies another supernova remnant, though this one is not for the faint of heart. Far older than the Crab, **Simeis 147** appears as a huge circular arrangement of slender filaments. Until recently, the object had been seen only in long-exposure photographs — though it's bright enough that many amateurs have captured it. However, observers at dark sites with large telescopes and Oxygen III filters have now detected the brightest portions of the nebula, which lie along the southern edge of the complex. **A**

Tom Polakis is an aerospace engineer living in Tempe, Arizona. His favorite astronomical pursuits are deep-sky observing and photography.

DECONSTRUCTING THE MILLENNIUM

The modern calendar may be based on astronomical movements, but this thousand-year hype is just a relic of our counting system.

by David Grinspoon

If I had to rate this millennium, I'd give it one thumb up and one thumb down. On the one hand, we've made major strides in understanding our place within the cosmic scheme, created countless great works of art and music, and learned how to preserve them for the ages. On the other, we've multiplied like vermin, invented and used several technologies of mass destruction, and shown a weakness for an "act first, worry about it later" approach to technological innovation that may be incompatible with global survival and peace. Any scout ships for the Union of Galactic Species that are considering us for membership will probably rate us as "potentially promising but a bit out of control" and pass along a recommendation to wait another millennium and keep an eye on us in the meantime.

Gary Baseman

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As purists will tell you, the millennium begins on January 1, 2001, because of the absence of a year zero. But, let's face it, if you're waiting until then to throw your millennium party, you're going to be too late. Just as people get more excited seeing a whole string of numbers on their odometer roll over instead of one, the move from 1999 to 2000 will be the event to remember.

"What's so special about the millennium?" many people have wondered. New Year's Eve has always been an anticlimax, a dramatic countdown to a clerical necessity, an excuse to drive around in search of a party or stay at home and watch that stupid ball drop in Times Square. So this millennium seems to be nothing more than a mega- (or kilo, I suppose) New Year's, the ultimate anticlimax. Curmudgeons and grinches have been whining that the millennium is arbitrary and meaningless and that there's really nothing to celebrate because all the fuss is over nothing. They're only partly right. This passage is not completely arbitrary, and it is certainly not meaningless.

More specifically, the complaint of arbitrariness can be broken up into several smaller ones: that there is nothing special about the number 1,000, nothing special that happened exactly 2,000 years ago, no physical significance to the passage of January 1, and that if Earth's orbit were a bit longer or shorter we'd be celebrating at different intervals. Let's take a look at each of these claims.

There is nothing special about the number 1,000. No known astronomical cycle repeats every 1,000 years. If we had other than 10 fingers, then our numerical and calendrical system would almost surely not be base 10, and 10^3 wouldn't seem like such a big deal. An odd number of digits seems unlikely, but 8 or 12 fingers would give us time passage raves at 512 or 1,728 years, respectively.

We could become binary over the next 1,000 years, and our digital descendants, who have long forgotten all about us, will be in charge of the celebration. In binary, 1,000 = 8, so those hypermachines could have a furious "millennium" celebration every 8 years. This cycle of celebration — the binary millennium — would have the advantage of being tied to a significant and nonarbitrary astronomical cycle: The cycle of Venus appearances repeats exactly every 8 years (give or take a day or two). Since Venus passes us on the inside orbital lane 5 times every 8 years, it repeats the same 5 paths in our morning and evening skies over this timescale. Wherever Venus appears tonight, perhaps setting in the evening sky, chasing the sun below the horizon, it will appear again on the same calendar date in 8 years. This fact was celebrated by Mayan priest-astronomers 1,000 years ago (more or less). Their calendar was pegged to this cycle, and thus the gods participated in their celebrations by adorning the sky with significant and reliably recurring celestial arrangements.

Nothing special happened exactly 2,000 years ago. Some people claim that the millennium will set the stage for the second coming of Christ. But his birthday celebration is on December 25, not December 31 or January 1. Besides, scholars argue about when he was actually born, and all seem to agree that it was probably in a warmer month and not in the year zero (especially since there was no year zero in the present system).

But we do seem to have a need to count things. And if we're to have a calendar, we need to be counting time from some date in the past. We don't know the dates of many significant events in our modern origin story — origin of the universe, formation of Earth, origin of life, extinction of the dinosaurs, birth of the first humans, and so on. We have pretty good estimates of when most of these milestones happened, but not with enough precision to count time from them in years. In order to have a precise calendar, we have to make something up, so there will always be an arbitrary component to our timekeeping. But that's not a reason to count a millennial passing as insignificant or not celebrate. Two thousand years marks a huge chunk of human history. It doesn't matter if its origins are arbitrary — it gains significance by virtue of being a globally acknowledged moment of mass awareness of the passage of large multigenerational stretches of time, providing an opportunity for public reflection on our history and possible destiny and for celebration of our existence on this planet.

There is no physical significance to the passage of January 1. I've often wished we could back the whole shebang up by 10 days and ring in the solstice. Then we'd have the cooperation of the sun in reminding us that time really is cyclical as well as passing, and we'd have something tangible and real to celebrate. The winter solstice marks a specific point in Earth's orbit — the point where the northern end of the tilted axis leans most directly away from the sun. For those of us living at northern midlatitudes, the low arc of the sun in the sky on that day reminds us of Earth's rather extreme tilt and that warmer and brighter days will inevitably follow. Solstitial awareness and celebration spans this millennium. Although 1,000 years ago no one on Earth, as far as I know, was thinking about orbiting worlds, a great many people at wide locations around Earth were highly aware of the significance of the solstice. The significance was much more immediate for members of pretechnological societies with a direct relationship between survival and cycles of growth, rainfall, and animal migration, all of which could be correlated with sky patterns.

Today, in addition to the imminent return of the warmth and light, we can celebrate having made it through one more 580-million-mile circle around the sun. And, if we regard January 1st as a belated solstitial celebration, then we're not completely flailing in the ether for temporal significance with which to justify our behavior on this night. Picture the spirit of Guy Lombardo doing a "Solstice Stomp" around Times

Square. Okay, maybe not. But if we think of the millennium as marking the completion of 1,000 orbits, the passage of 1,000 solstices, then maybe there actually is something to celebrate — especially since it was only during this millennium that we realized that there was any such thing as an orbit and that Earth, previously believed to be the immovable center of the universe, was moving along one. During the past 2,000 orbits we have mentally traveled from the chosen center of a rather limited universe to a minuscule and random corner of an unbelievably vast one. And physically, just by hanging on to this spinning rock, we've orbited more than 1 trillion miles, or almost 1/20 the distance to the nearest star.

During this time the sun hasn't been just sitting there, either. In this same 2,000 years, the sun has traveled almost 9 trillion miles along its orbit around the center of the Milky Way Galaxy, and we've been along for the ride. This arc equals a tiny portion (about three-thousandths of a degree) of a galactic orbit. In the span of a "galactic year," the sun travels 10^{18} miles, roughly the distance to the Magellenic Clouds, the nearest companion galaxies. One complete orbit takes 240 million Earth years. Now surviving one of those would really be something to celebrate. So far we humans have made it around about six degrees of one galactic orbit. One galactic year ago, the dinosaurs were the new kids on the block and we mammals were just a gleam in Earth's eye. One galactic year from now, the human race will either be thriving and living sustainably on several worlds or we will have gone the way of the dinosaurs and most species that have ever lived. The dinosaurs made it through three-quarters of one of these galactic years until a stray comet with their name on it sent reptilian evolution back to the drawing board and opened up expansion opportunities for the mammals, which we jumped all over.

Of course, the Galaxy has also been moving relative to other galaxies during this time, but let's not even think about that because if we do we'll have to deal with the fact that we have no absolute reference frame within which to measure any of these motions. At least with the time dimension, we can pick an arbitrary date and then measure absolutely from this (assuming that atomic and orbital clocks aren't conspiring to fool us about the steady linearity of time). But with space, we don't even have a way to put down an arbitrary mooring from which to measure distances that isn't obviously moving with respect to everything else.

If Earth's orbit were longer or shorter, we'd just be celebrating at different intervals. At first glance this appears to be a tautology — obviously true. But, think again: Since the 17th-century insights of Kepler and Newton, we've known that a planet's orbital period has a specific mathematical relationship to the distance from, and mass of, the star that it's orbiting. If the year were a different length, then either Earth would be at a different distance from the sun, or the sun would be a different type of star, or both. If its orbit were tweaked just a little bit, then Earth would probably still have a thriving biosphere, but our climate would have evolved differently and natural selection might have made different choices. Especially when we consider the role that chance and chaos may have played in biological evolution, a minor change in Earth's orbit might have produced an unrecognizable biosphere. Similarly, a more massive star would be hotter and burn out more quickly, and a lighter one would be cooler, with implications for terrestrial evolution. Going back to Earth's birth, if its orbit had been even slightly different, the collision that formed Earth's climate-steadying moon would not have occurred and Earth could be lifeless, or at the very least another world altogether where Guy Lombardo and the artist formerly known as Prince might never have been born. So the specific length of an Earth year is inextricably bound to aspects of planetary history and physics that allowed Earth to arrive at our present-day existence. If the year were a different length, "we" might not be here to celebrate at all.

The heavens will not align to mark the millennium for us, but this millennial passage will be the first observable from space. Although rationalists through the millennia have insisted that there is nothing to fear from this passage, that the world will not end, and that prophets of doom are superstitious fools, ironically, this time they may be wrong. Now there really is something to fear — something that I've heard described as the white man's voodoo coming back to haunt him. I speak, of course, of the "Y2K bug," the inadvertent, digital time bombs programmed into much of our software and hardware that may go off at midnight when 1999 becomes 2000, beginning the new millennium with chaos born of technological shortsightedness. So, if anyone watches, the view from space as the millennium passes on Earth may include, in addition to a wave of pyrotechnic displays sweeping along the antisunward point as midnight falls on consecutive time zones, the dimming of the lights as power grids fall and the blooming pyres of revelers and rioters. Most likely the problem has been massively overhyped, but it certainly contributes to premillennial anxiety and has cost millions of dollars in reconfigurations. I can't help wondering what were they thinking, the techogeeks who created so many of our computer programs: Whether they thought that the year 2000 would never come to pass or all their programs would be obsolete by then. More likely they were just solving a short-term problem, maximizing near-term efficiency and profit. So now we all get to enjoy the suspense.

Let's hope that the passage of the next 1,000 solstices finds us without our digital pants down — especially if those galactic scout ships are lying in wait.

David Grinspoon is a scientist at the Southwest Research Institute.

ask Astro

Winter Solstice, Globular Clusters

The shortest day of the year in the Northern Hemisphere usually occurs on December 21. But the earliest sunset occurs earlier in December because of the effect of Earth's elliptical orbit around the sun. In this picture, the sun is setting over Sicily. Gianni Tumino

Q: Can you explain why the earliest sunset occurs on December 8, while the shortest day of the year is December 21? — *Linda Burkhard, Cherokee, Iowa*

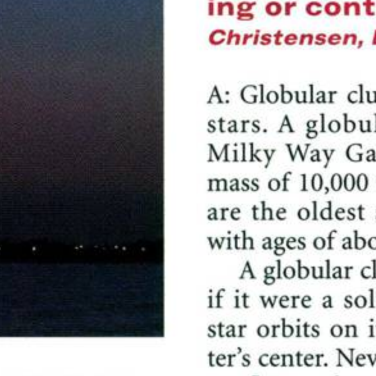
A: If Earth orbited the sun in a circle, and if Earth's axis were perpendicular to the plane of its orbit, the shortest day and the earliest sunset of the year would coincide. As you know, it is more complicated.

The shortest day of the year in the Northern Hemisphere is a function of the tilt of Earth's axis. It occurs on the winter solstice (on or about December 21). On that date, the Northern Hemisphere points as far from the sun as it can, and the sun's path across its sky is the lowest of the year. Because the sun's path is lower, it's also shorter, which is why the day is short.

During the year, the speed of the apparent motion of the sun against the background stars (a reflection of Earth's motion around the sun) changes. When Earth is closest to the sun on its elliptical orbit, the sun appears to move faster than when Earth is farther away. This also changes the length of the day.

Therefore, the times of sunrise and sunset depend on two things: the season and Earth's elliptical orbit. That's why the shortest day and earliest sunset don't coincide. These two effects together govern what is called the Equation of Time, which is what astronomers use to determine when the sun rises and sets each day during the year.

An excellent description of this can be found at Nick Strobel's Astronomy Notes website at www.bc.cc.ca.us/programs/sea/astronomy/book.htm. — *Phil Plait, Advanced Computer Concepts, Inc.; check out his website at www.badastronomy.com*



Globular clusters such as M92 are not static. They are gravitationally perturbed by the Milky Way Galaxy and can lose outer stars via "evaporation." Jack Newton

Q: Do globular clusters rotate? Are they expanding or contracting? — *Bob Christensen, Belen, New Mexico*

A: Globular clusters are collections of stars. A globular in the halo of the Milky Way Galaxy can have a total mass of 10,000 to a million suns. They are the oldest systems in the galaxy, with ages of about 12 billion years.

A globular cluster does not rotate as if it were a solid body. Instead, each star orbits on its own about the cluster's center. Nevertheless, some clusters are flattened, so there seems to be a net rotation superimposed on the orbits.

Globular clusters are dynamic. As the stars orbit, they continually pass close to one another and share energy through their mutual gravity. In such encounters, some stars speed up while others slow. If a star moves faster, its orbit expands. The fastest ones travel in the cluster's outer regions.

Clusters also are subject to gravitational tides raised by the galaxy. As these tides stretch the clusters like taffy, the outermost stars can move so fast that they escape the cluster. In this way, a cluster can slowly "evaporate." The remaining stars sink toward the center, causing the cluster's core to collapse.

Globulars therefore expand and contract simultaneously. Thinly populated clusters evaporate altogether; however, globulars that remain today are rich enough to have survived. Their appearances depend on their mass and their location in the galaxy. — *Jim Kaler, University of Illinois; he describes a new star each week at www.astro.uiuc .edu/~kaler/sow/sow.html*

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10 TOP P

Astronomy's editors picked their top ten sky events of the 20th century. Though we have our own favorites, we'd like to know what yours are. With that in mind, let's journey back through the last 100 years.

⑩ Deep Impact: Tunguska

Earth shuddered and seismometers registered the blow. The explosion was heard across continental Europe. The impact was so large that it flattened an entire forest, yet left no crater. In all likelihood, the 1908 Tunguska event was the result of a small comet or fragmenting asteroid exploding above Earth's surface. Had the impact occurred just eight hours later, ground zero would have been near the Russian city of St. Petersburg.

Fireballs have also achieved notoriety this century. One such event was the daylight fireball of August 10, 1972, when an object skimmed the atmosphere over the Grand Teton mountains. It was viewed and photographed by dozens of vacationers. The 1990s saw the Peekskill fireball fly over Pennsylvania and New York states, eventually crashing through the trunk of a car. What great impacts will the next century bring?

⑨ Auroral Displays of the Late 20th Century

The sky comes alive during a bright aurora, and the late 1980s and early 1990s provided some of the most spectacular displays seen this century. Coronal mass ejections from the sun carry highly energetic particles that pump energy into Earth's magnetosphere, accelerating electrons and causing them to cascade into our atmosphere around the magnetic poles. Such events induce electric currents in Earth's surface and created the March

Jay Brausch

ICKS

by Martin Ratcliffe

1989 blackout in Quebec when six million people lost power for six hours.

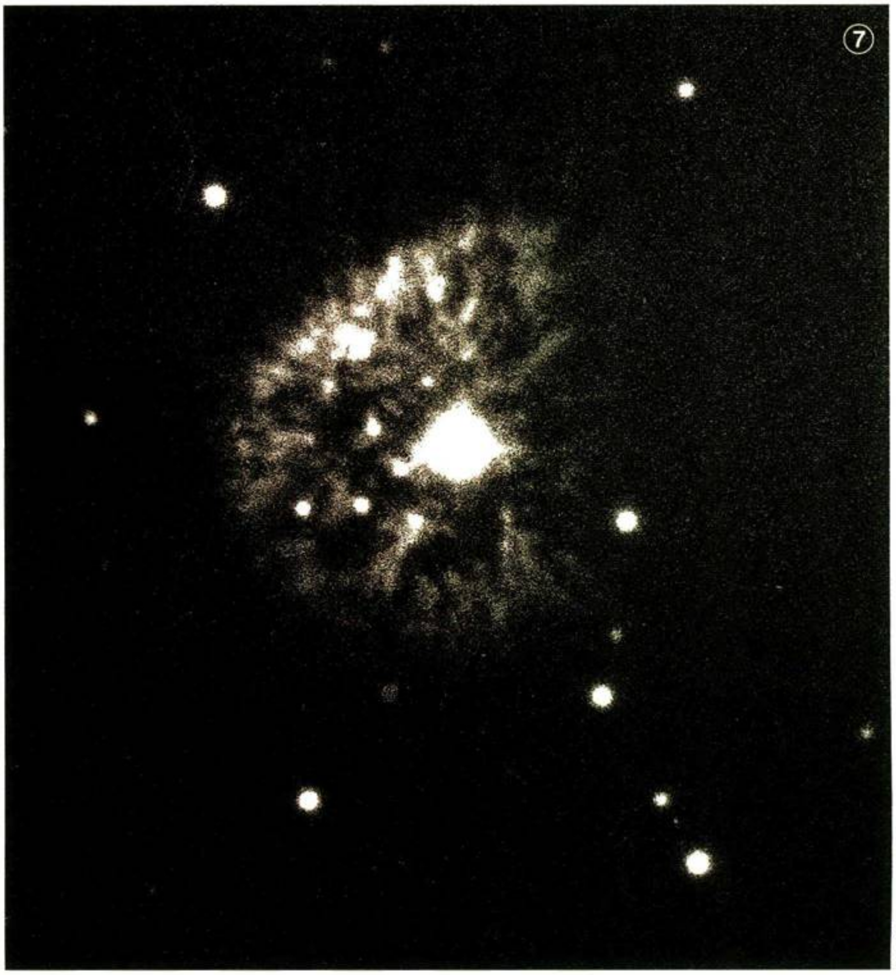
❽ The Giant Sunspot of 1947

Nothing has yet matched the giant sunspot that crossed the solar disk three times in 1947 from February 5 to its last view on April 12. Its total area was 6 billion square miles, about one percent of the total apparent area of the solar disk and the size of more than 100 Earths. The spot began as a group of small spots first noticed on February 5. By February 7, the group was large enough to be seen with the naked eye. One solar rotation later, these spots had become significantly larger and appeared to be coalescing. On its third passage, visible beginning on March 30, the group was more diffuse and spread out over a larger area. It broke all records and today remains the century's greatest sunspot.

❼ Nova Persei

The 20th century held a wealth of novae. In 1918, Nova Aquilae reached magnitude –1.1, far brighter than any nova in modern times. On November 11, 1942, Nova Puppis peaked at a magnitude of 0.3, while Nova Cygni (magnitude 1.8), in 1975, is perhaps the most memorable in recent times. Although these events were certainly impressive, the most enigmatic nova occurred in 1901.

The Scottish amateur astronomer Thomas Anderson first spotted Nova Persei's 2nd-magnitude glow on February 21, 1901. Just two days later it reached magnitude 0.2, ranking it as the second brightest nova of the past 100 years, then faded rapidly and began to oscillate in brightness. It dipped in and out of naked-eye visibility for several weeks. But Nova Persei held a further surprise.



Hale Observatories

A nebula observed around the nova during the summer of 1901 held the attention of astronomers. They were puzzled by an expansion that seemed to be moving at the speed of light. This phenomenon was soon explained as the flash of light from the nova illuminating a previously dark gaseous nebula. Nova Persei is still observable today, though it is better known as the variable star GK Persei. It hovers around magnitude 13 but on occasion brightens to magnitude 11.

❻ The 1909 Opposition of Mars

It was the 1909 opposition of Mars that dealt the final blow to the planet's proposed canals. During the 1877–8 opposition, the Italian astronomer Giovanni Schiaparelli discovered a series of linear features on Mars. His term "canali" — mistranslated into English as canals — produced one of the most bizarre stories in the history of planetary research.

Observations by Percival Lowell and his assistants, William Henry Pickering

Arthur Scott Murrell

and Andrew Ellicott Douglass, fired up the debate. They drew an enormous number of straight, dark features crisscrossing the ruddy martian landscape. By 1906, Lowell announced his interpretation: They were evidence for a martian civilization that had built a network of intricate canals to transport precious water from the poles to arid regions. A vigorous debate ensued. George Ellery Hale was vocal in his opposition and claimed support from his own observations. He noted "no trace of a geometrical reseau" and showed that the linear features were "resolvable" into individual dark spots when viewed with larger telescopes. Still, the controversy continued.

It was the accuracy and skill with which Eugene Michael Antoniadi drew the martian disk that helped put the controversy to rest. Using the Meudon 32-inch refractor during the 1909 opposition, Antoniadi watched the rectilinear "canals" disappear at the moment when very delicate details became clearly visible. These details were beyond the range of Schiaparelli's or Lowell's refractors but were confirmed by photographs.

❺ The 1910 Return of Halley's Comet

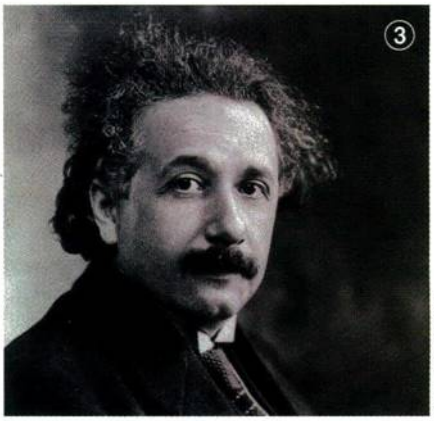
Suggesting the best comet of the century is fraught with pitfalls — there are nearly as many opinions as there are astronomers. However, Comet Halley's role in defining cometary science is unsurpassed in this century.

The scientific study of comets truly began in the 20th century, and though Comet Halley wasn't as spectacular as Hale-Bopp, Hyakutake, West, or any of half a dozen other bright comets, it stands above all others for the unprecedented scientific data it provided. Following the comet's 1835 appearance, astronomical observation techniques advanced considerably. Photographic plates and spectroscopy provided more information about the comet's 1910 return than all previous apparitions combined. The vast quantity of data led to the evolution of important ideas on the composition of comets. Though comet spectrograms had been taken prior to Halley in 1910, no viable theory on how the spectral lines formed had been presented. In 1911, Karl Schwarzschild and Erich Kron suggested fluorescence as the mechanism. Molecules in the comet's tail are excited by solar radiation at specific wavelengths, and these molecules then reemit that radiation as they return to their de-excited state.

Hale Observatories

❹ The 1966 Leonid Meteor Storm

Each year, Earth passes through the stream of debris left in Comet Tempel-Tuttle's wake. The comet rounds the sun in a 33-year orbit, and three times each century we pass through the densest part of the stream. For a short time during the morning of November 17, 1966, we passed through just such a region, and the sky rained meteors too rapidly to count. One observer reported an estimated 50,000 in one 20-minute interval. So many "shooting stars" were seen that the appearance of the radiant was evident by the foreshortening of the stream of particles. Earth appeared to be traveling through a snowstorm, and some fireballs were bright enough to cast shadows.



Yerkes Observatory

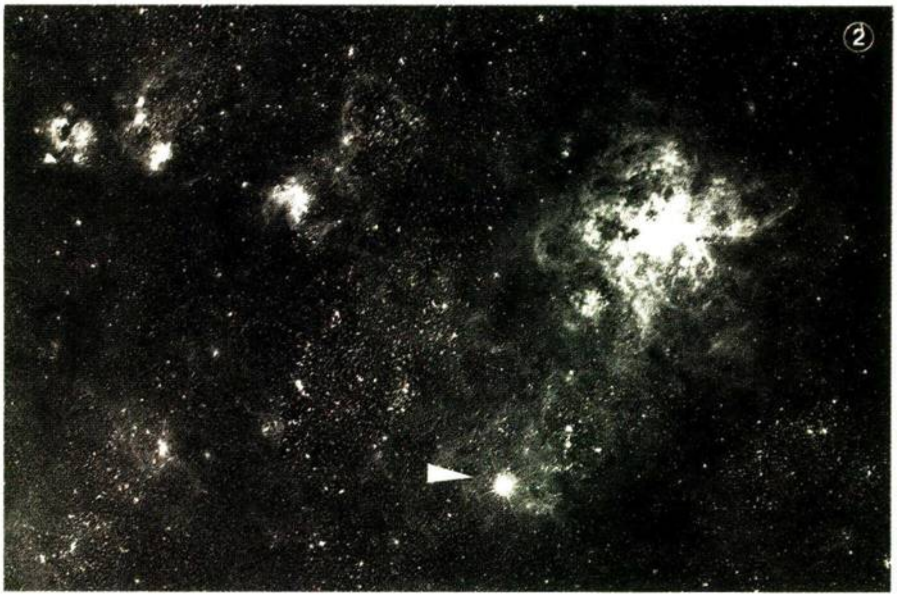
❸ The May 29, 1919, Total Solar Eclipse

Though the longest total solar eclipse (7 minutes and 8 seconds) this century was on June 20, 1955, the May 29, 1919, eclipse far outshines it. In 1915, Albert Einstein had completed his general theory of relativity, which describes how massive objects distort the space around them. "It follows," wrote Einstein, "that rays of light passing close to the sun are deflected by its gravitational field, so that the angular distance between the sun and a fixed star appearing near to it is apparently increased by nearly a second of arc." Realizing that a total solar eclipse provided an extraordinary opportunity to photograph the starfield in the same line of sight as the sun, Einstein encouraged astronomers to perform the experiment.

The British organized two expeditions. One to Sobral, in northern Brazil, and another to the island of Principe off the African coast. Astronomers photographed the eclipse and repeated the exposure some months later without the sun in the region. The observed deflection was very close to the value Einstein had predicted and double the effect predicted by Newtonian gravitational theory. Einstein's stature was forever sealed, and the way we look at the universe was forever changed.

❷ Supernova 1987A

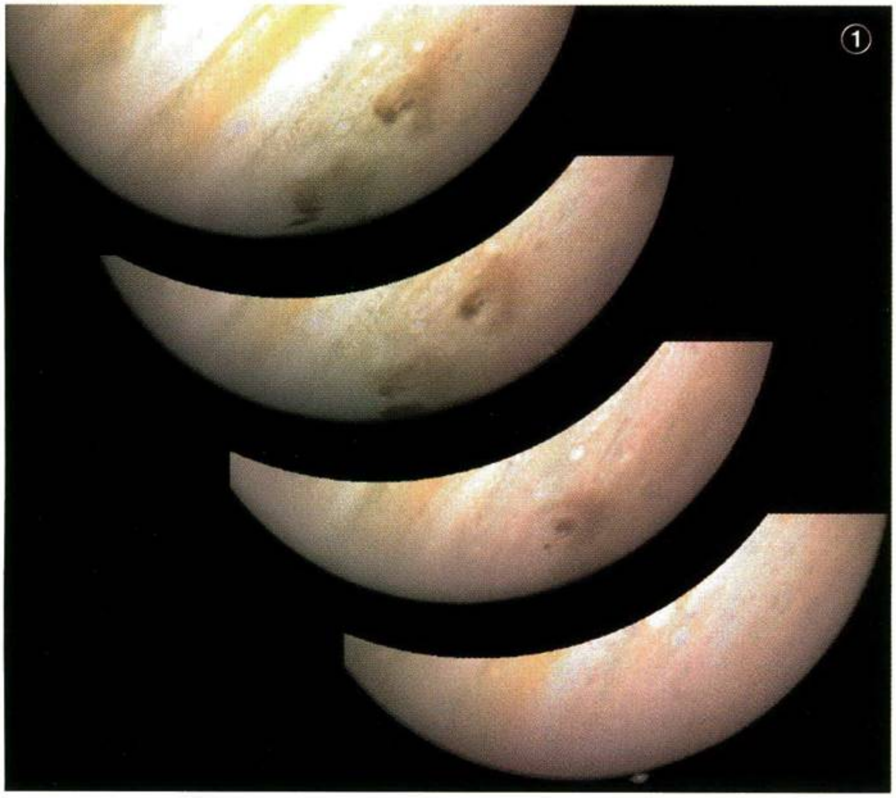
The first naked-eye supernova in 383 years appeared on February 24, 1987. Supernova 1987A emerged when the 20-solar-mass blue supergiant star Sanduleak –69°202 exploded. Ian Shelton caught the dying star on film at Las Campanas Observatory in Chile. Evidence of the supernova was recorded simultaneously by underground neutrino detectors in the United States and Japan — the first time the signature of a star's collapsing core had been detected. Just months after its discovery, orbiting observatories detected the gamma-ray signature of radioactive elements formed in the collapsing star's core reactions. This confirmed the widely held theory that supernovae produce many of the heavy elements we find on Earth.



Wendy Roberts/Harvard-Smithsonian Center for Astrophysics/NOAO

❶ Shoemaker-Levy 9's Crash into Jupiter

The top event of the century was unlike any observational event in history. From July 16–22, 1994, twenty-one fragments of Comet Shoemaker-Levy 9, discovered as a "string of pearls" in 1993, streamed toward Jupiter at 40 miles per second. Each fragment penetrated the jovian atmosphere faster than a bullet. Sudden shock heating caused explosive expansion of both the comet's and Jupiter's atmospheric gases. The explosion erupted back up the newly created entry tube and blasted cometary dust 2,000 miles above the jovian cloud deck. By midweek the inky-black spots gave Jupiter an eerie appearance, as if two black eyes were staring at Earth. The largest impact, caused by fragment "G," struck with the equivalent energy of 6 million tons of TNT. If such an impact occurred on Earth, the resulting crater would be 40 miles across.



STScI

Today, many of us can go out and make a major observation because our basic knowledge has taken giant strides during the past century. Professional astronomers in the first decade of the 1900s contemplated fuzzy patches of light called spiral nebulae. Now amateurs can guide their computer-controlled telescopes with cooled CCD cameras and image in seconds what took Edwin Hubble hours and hours to complete. But you don't need high-tech equipment to experience the universe. All you need is a pair of eyes and occasionally binoculars or a telescope to join the adventure. You never know what will happen next in the sky. ▮

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. He writes Astronomy's *monthly Sky Show column and authored our 2000 Guide to the Sky (*Explore the Universe 2000*).*

Cast Your Vote

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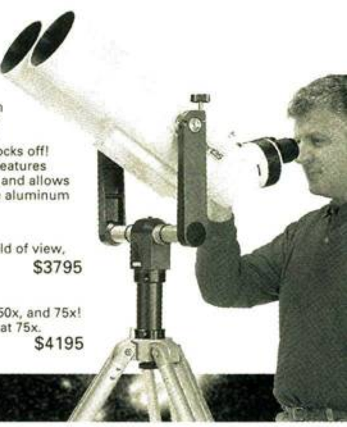

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The closest star offers a multitude of features to patient observers.

by Phil Harrington

TELL PEOPLE YOU'RE ABOUT TO STUDY A STAR AND THEY'LL expect to hear some exotic name from a Milky Way denizen dozens of light-years away. When instead you say you're going to study our sun, watch for a reaction more feigned than genuine. Too bad. Anyone who really studies the sun discovers a fascinating star in virtually his or her own backyard. Payback on your efforts doubles when you realize — and announce to any doubters — that the sun is unique among stars: Although most sky objects appear static through backyard equipment, the sun always displays some degree of activity, thanks to its dynamic surface.

The time to observe the sun is now. The sun increases and decreases in activity over an 11-year cycle, and solar physicists expect maximum sunspot activity between January and April 2000. The last such maximum occurred in 1989. So ready your equipment and your knowledge. Before you rush outside to begin your observations of "Old Sol," however, consider another unique trait that separates our star from the others. As the only celestial object capable of causing physical harm to unprotected eyes, all sungazers must proceed with caution. Remember — the safest way to look at the sun is not to look at it.

SOLAR PROJECTIONS

Look at the sun without looking at it — impossible? Not really. Just use your telescope as a solar projector. Sunlight passing through a lens projects an image into the eyepiece and onto a screen, just like a slide or movie. Change the size of the sun's image by moving the screen closer or farther from the eyepiece, then use the focusing knob to clarify the image. A smooth, white surface works best for the projection screen. Any irregularities degrade image quality. Avoid a washed-out image by positioning the screen in shadow rather than direct sunlight. Newtonian reflectors offer viewers an advantage because the eyepiece protrudes from one side of the instrument, easing image adjustment. Observers using refractors or Cassegrain scopes will achieve the best results with a star diagonal, which also projects the image to the side of the scope. The star diagonal prism flips the image right-side-up for viewers. In order to use binoculars for projecting an image, cut out a cardboard light block and attach it securely over the outside of the lens barrels. Prevent overlapping image projection by capping one side of the binoculars.

Regardless of the method or instruments used for solar projection, prolonged viewing often overheats both telescope and eyepiece optics. Aim the scope at the sun for no more than ten mintues and then point it away from the sun for a few minutes to let it cool. Also, consider using an inexpensive eyepiece just in case any damage occurs.

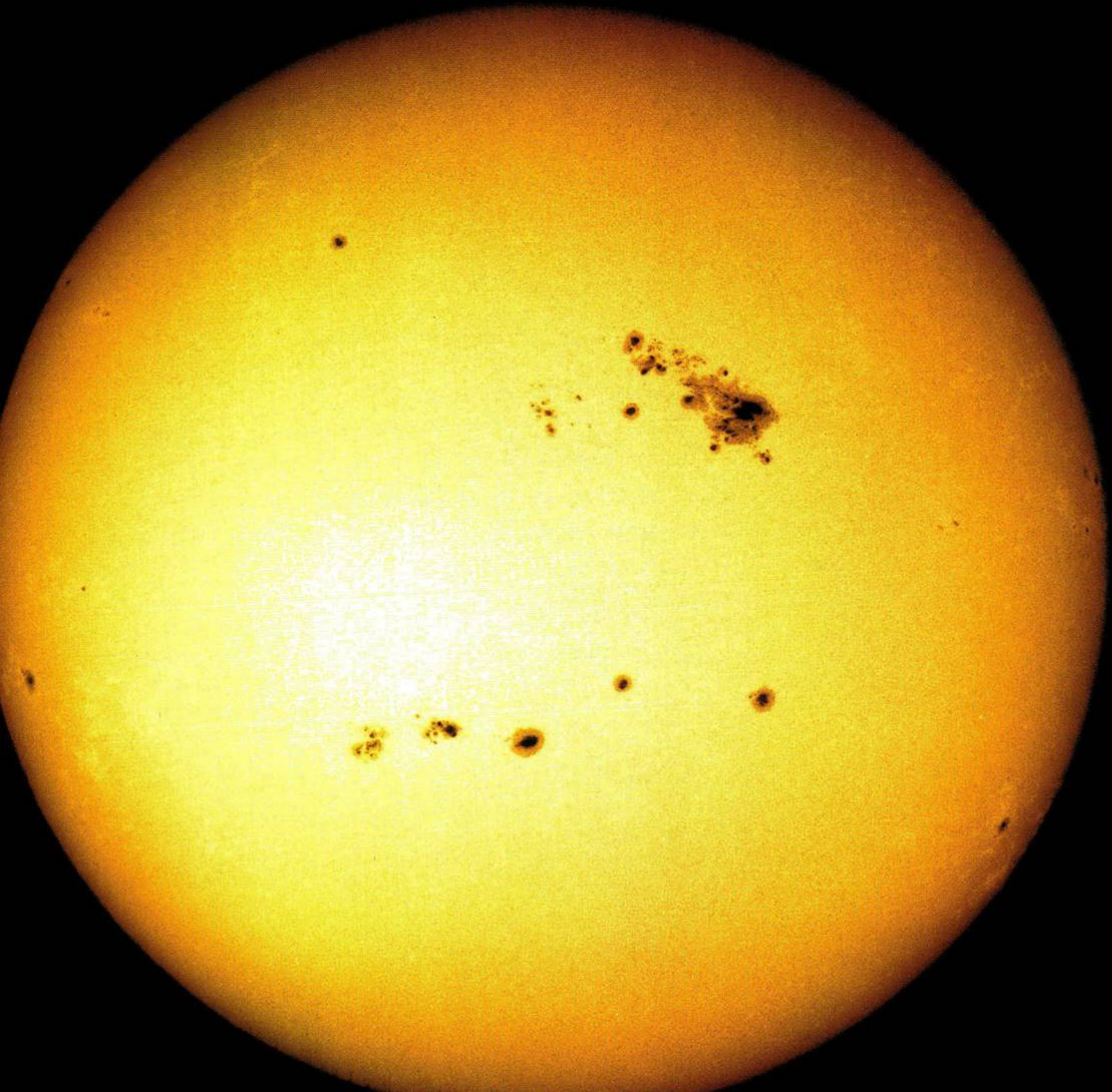
SOLAR FILTERS

Many seasoned solar observers prefer solar filters to projection. Solar filters allow direct viewing and show the greatest amount of detail. Only use solar filters designed to fit over the front of the telescope (or binoculars). Positioned correctly, these filters reduce dangerously intense solar rays prior to entering the telescope and your eyes. Never place a solar filter between your eyes and the eyepiece.

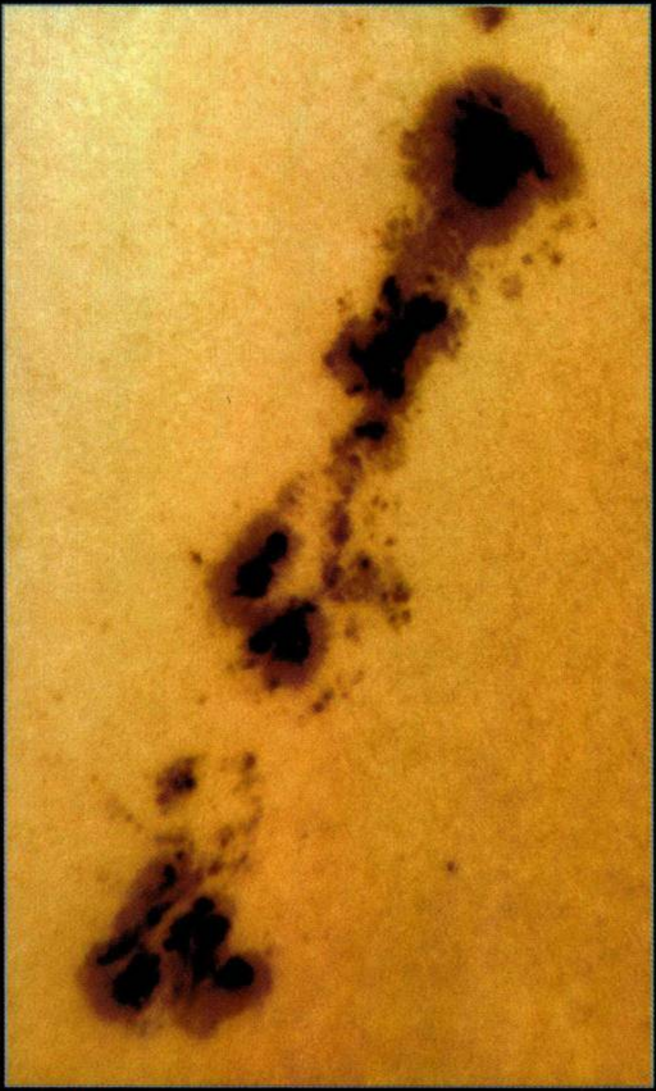
Solar filters are composed of either nickel-coated glass or aluminized Mylar. Both reduce the sun's visible intensity as well as its dangerous ultraviolet and infrared radiation to within safe viewing levels. Choice of one material over another depends upon the observer's preference. Most glass filters produce an eye-pleasing orange, yellow, or peach colored sun instead of the light-blue disk seen through Mylar filters.

With use of glass filters comes the possibility of marring image quality. Viewing the sun through a glass filter is comparable to observing through a window. Substandard glass filters degrade the optical quality of an otherwise fine telescope. Personal testing of many glass and Mylar solar filters from various manufacturers helped me determine that most are perfectly fine for visual observations of the sun (up to about 200x). Regardless of the chosen viewing method, never look through the telescope's finder to aim the instrument. (Prevent this mistake by leaving the dust cap on your finderscope.) Aim the telescope by watching its shadow as you swing the instrument back and forth. When the shadow is the shortest, the telescope is pointed at the sun.

Readers without telescopes or binoculars can view sunspots on the Internet. Several websites post daily images of the sun. Locate a favorite site at http://www.bbso.njit.edu/.

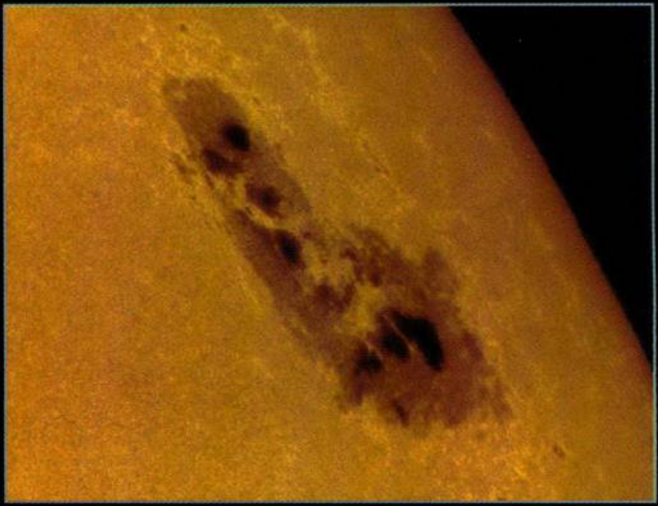


SOL'S CHANGING FACE



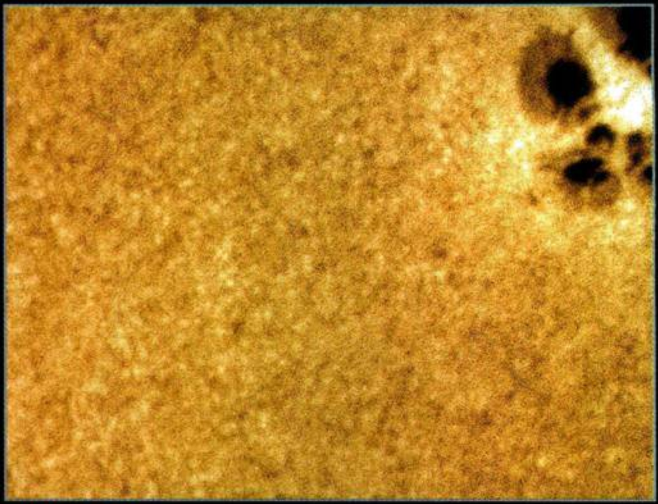
Lee C. Coombs

SUNSPOTS: Relatively cool magnetic storms traverse the sun's face almost constantly and appear in great numbers at solar maximum.



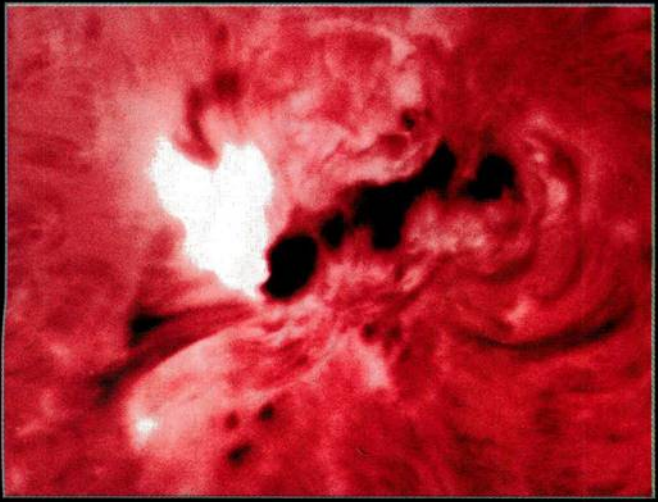
Gordon Garcia

FACULAE: Bright patches in the upper photosphere occur around darker sunspots; they are best seen near the sun's limb.



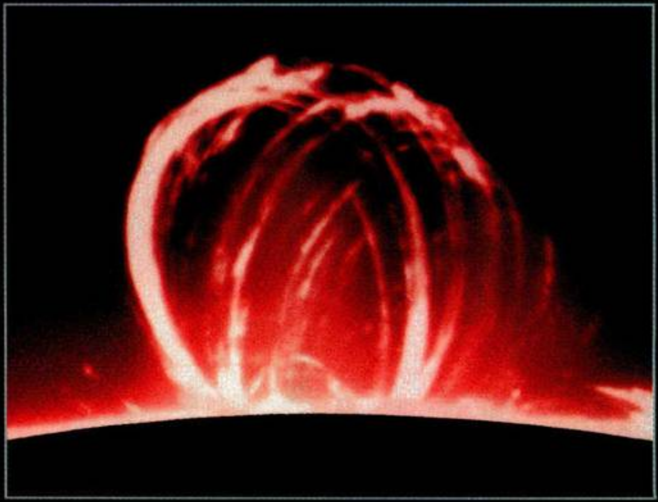
Jean Dragesco

GRANULATION: Bright, irregularly shaped granules in the photosphere are convective cells that carry hot gases upward.



Randy Tatum

FLARES: Sudden, intense brightenings of the chromosphere or upper corona allow blasts of radiation to leap outward into the solar system.



Jean Dragesco

PROMINENCES: Surging clouds of ionized gas are best visible along the limb; loop prominences can tower tens of thousands of miles high.

THE OBJECTS OF YOUR ATTENTION

Now that you know how to look at the sun, just what are you looking for? Either solar projection or solar filter methods allow observation of the sun's photosphere — the lowest of three layers that compose the solar atmosphere. For most amateur astronomers, the biggest attraction of sungazing is watching the photosphere's ever-changing array of sunspots. The largest sunspots are visible to the naked eye and were followed by Chinese astronomers thousands of years ago. First telescopically observed in 1610 by Galileo in Italy, Thomas Harriot in Britain, and Fabricius and Christopher Scheiner in Germany, sunspots are cool magnetic "storms," transitory features that appear in unusually strong regions of the sun's powerful magnetic field.

Energy pouring outward from the sun's core creates strong magnetic currents that ebb and flow. Temperatures in the adjacent photosphere sometimes drop by as much as 1,500° K, resulting in cooler areas that appear darker by contrast. "By contrast," is the key phrase here: magically place a sunspot in the night sky and it would outshine the full moon.

Each sunspot consists of a very dark central portion, the umbra (Latin for "shadow"), surrounded by a slightly lighter shadow ring called the penumbra ("almost shadow" in Latin). These areas range in size from hundreds to thousands of kilometers in diameter.

Although some sunspots are large enough to view through binoculars, or even the unaided eye with proper filtering, most require a telescope. Sunspots often form in groups, with the largest spanning several Earth diameters across. Groups typically consist of one or two larger sunspots surrounded by several smaller members.

Successful sunspot viewing depends not only upon the optical quality of equipment used, but also upon the steadiness of Earth's atmosphere. Pavement, for instance, reradiates image-ruining infrared (heat) waves. Observers can lessen atmospheric interference by setting up telescopes in a grassy yard or field rather than a parking lot.

SUNSPOT CYCLES

Sunspot numbers fluctuate within the sunspot cycle. Toward sunspot maximum, dozens — even hundreds — of individual sunspots are present, often clustered into large groups. When the cycle nears sunspot minimum, the solar disk can appear completely barren.

In 1848, Johann Rudolph Wolf, one of the 19th century's foremost solar observers and later director of the Zurich Observatory, confirmed the existence of the sunspot cycle. Wolf determined that the cycle lasts 11.1 years, a number still generally accepted. Further observations show that the asymmetrical sunspot cycle takes an average 4.8 years to rise from minimum to maximum activity, then drops from maximum to minimum in about 6.2 years. Every cycle varies, with intervals between sunspot maxima lasting as few as eight years to as many as 16 years. Some solar astronomers also suspect that 80- and 240-year periods are superimposed on the 11-year sunspot cycle.

Wolf also devised a method for recording the level of sunspot activity with the sunspot number referred to as the Wolf Sunspot Number or Zurich Sunspot Number. Although convoluted, this methodology is still used today. The sunspot number reflects more than the number of sunpots visible; rather, the Wolf method first counts the number of sunspot groups, multiplies that count by ten, then adds to this the number of individual sunspots.

Because sunspots change so quickly and their visibility varies greatly from one observation post to the next, astronomers base the current sunspot number on a weighted average of measurements taken daily from a network of cooperative observatories. The greatest sunspot activity ever recorded occurred during the 1957 maximum, with a mean Zurich Sunspot Number of 190.2.

Despite the mercurial nature of sunspot size and number, sunspot location on the sun is not as random. In 1904, British astronomer E. W. Maunder determined that the first sunspots in a new cycle form at high latitudes — 30° to 40° — and then gradually form increasingly at lower latitudes as the cycle continues. Also, the early spots in a new cycle overlap in time with the last spots in the old cycle.

Maunder also discovered that no sunspots at all appeared from 1645 to 1715, a period now called the Maunder minimum. This period of diminished sunspot activity coincided with the "Little Ice Age" in Europe. Critics note that other factors, such as suspended volcanic aerosols, may also have affected global temperatures during that period.

LOCATION, LOCATION, LOCATION

Galileo studied sunspot location and movement and determined that the sun rotates on its axis. Amateur sungazers can duplicate these historic observations. Photograph or make a pencil sketch of the sun's disk every second or third day over a span of a month. Each successive sketch should show how sunspots appear to move as they change in size and shape. Several months of observation reveal that spots at different latitudes on the sun rotate at different speeds. The sun's equator rotates once every 25 days, while the north- and south-polar regions take approximately 36 days.

Observers may also notice the opposite of sunspots, brighter areas of the photosphere know as faculae. Faculae form hundreds of miles above the visible photosphere. Watch for faculae at the edges, rather than the center, of the sun's disk. Here the light-dark contrast is greatest thanks to an effect called "limb darkening." Limb darkening occurs because earthbound viewers can't see as deeply into the sun at the limbs, so we see higher, cooler, and thus dimmer regions.

Careful study of the photosphere shows that is it not smooth, but composed of a myriad of tiny "grains" called granules. Each granule is a convective cell of heated gas measuring between 400 and 600 miles across. As the gas rises and reaches the top of the photosphere, it cools, then drops back into the photosphere to be reheated and recirculated, like a pot filled with cells of boiling water on a stove top. Granulation viewing requires at least a 3-inch telescope, 150x to 200x, and very stable atmospheric conditions. Less-than-perfect weather or optics blur the granules, making them impossible to resolve. Granulations are also nearly impossible to spot using solar projection methods.

STAR LIGHT, STAR BRIGHT

So why wait? The sun is an ideal amateur target for study through backyard telescopes. It is visible at a convenient hour. In-depth observations are possible without expensive equipment. As we approach maximum in the sunspot cycle, our star promises an interesting show.

Phil Harrington is a frequent contributor to Astronomy *who observes the sun from his home in New York.*

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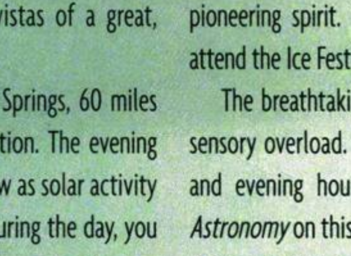

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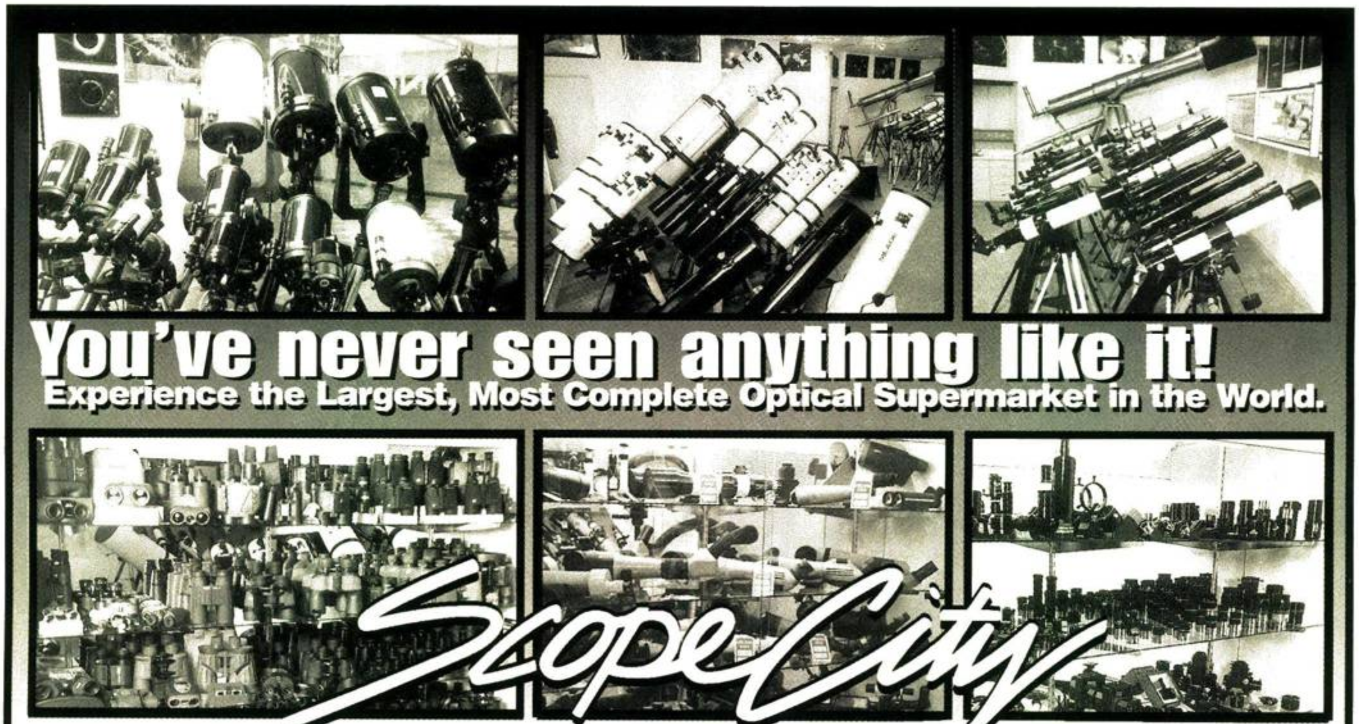
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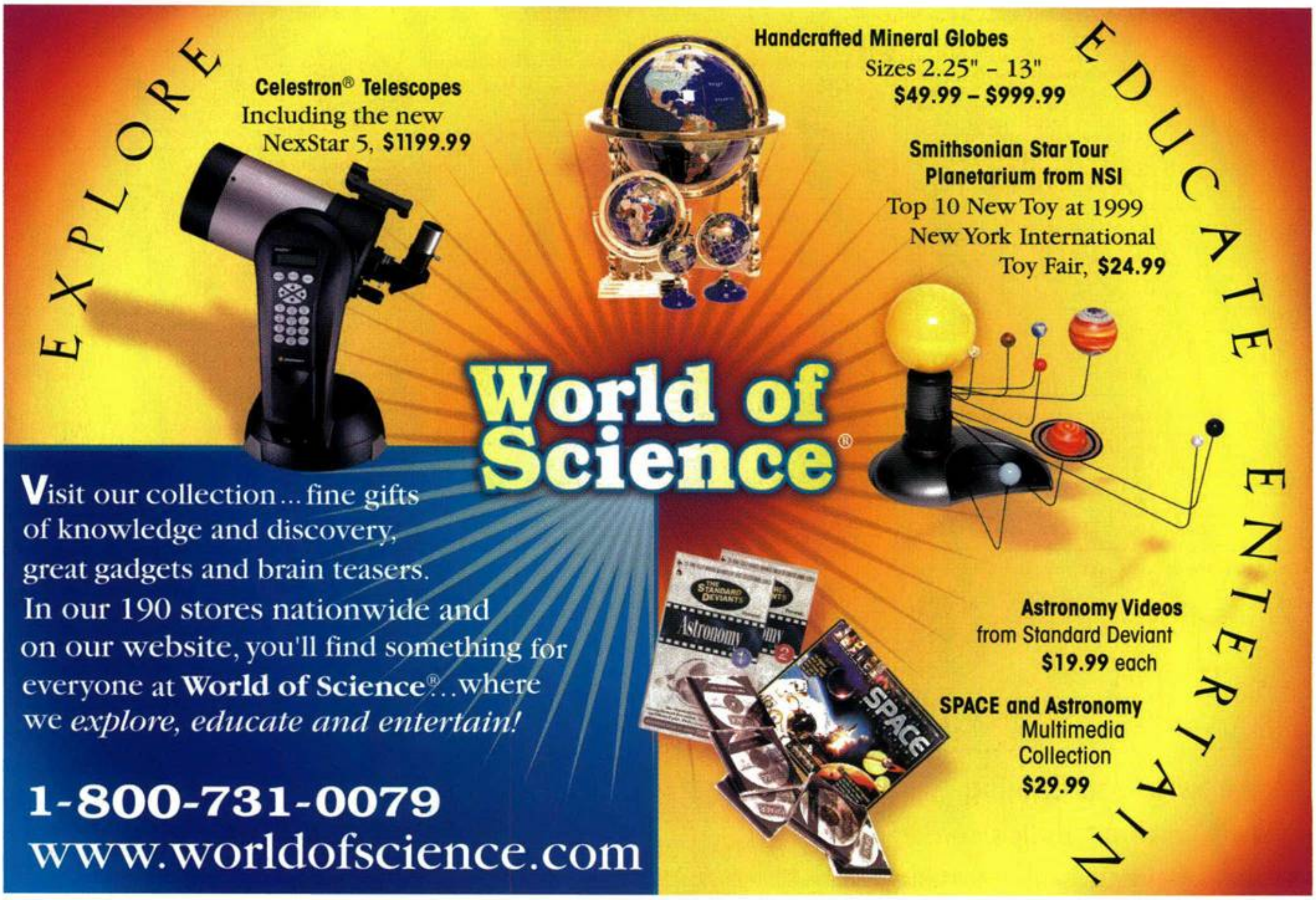

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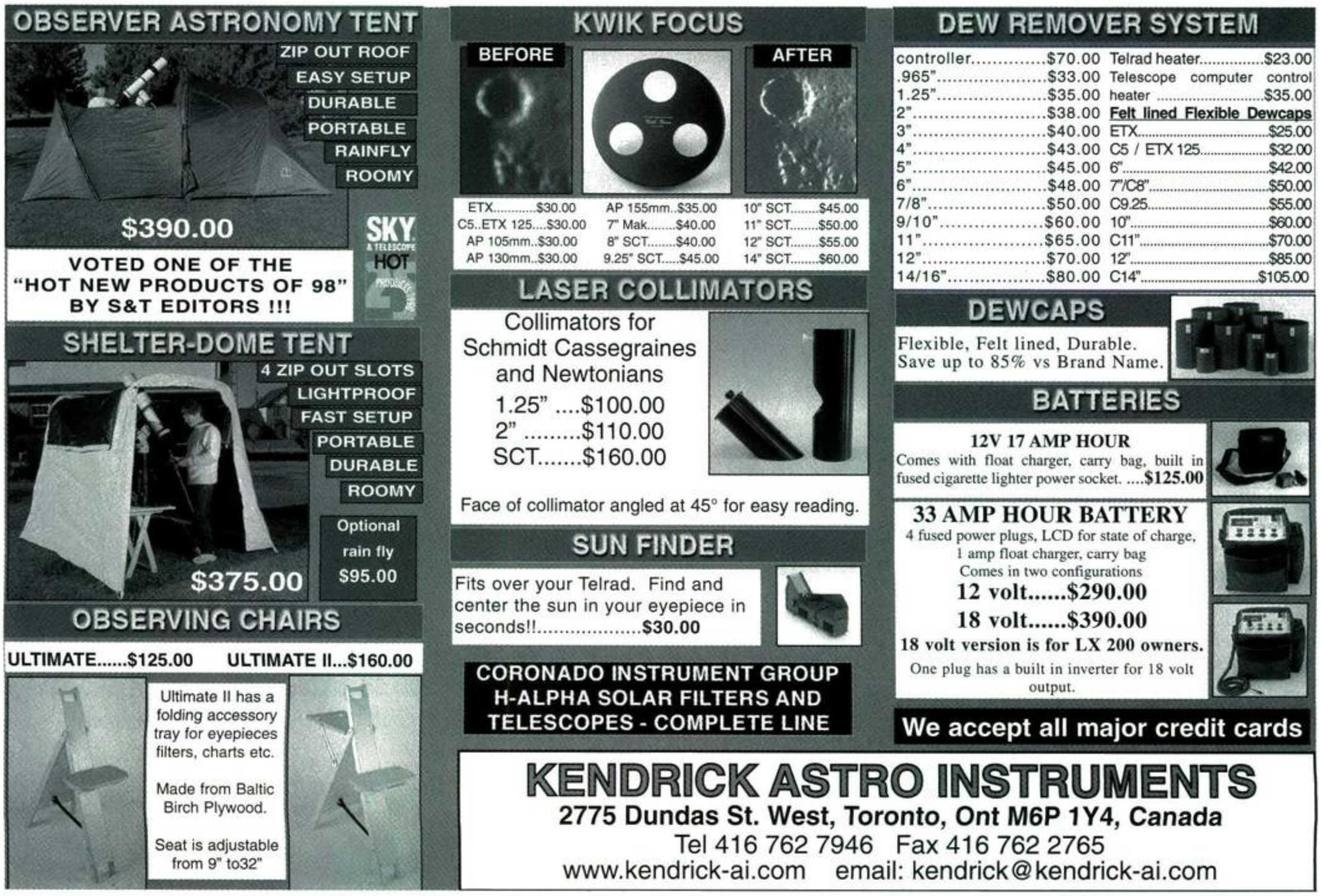
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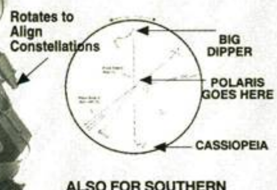

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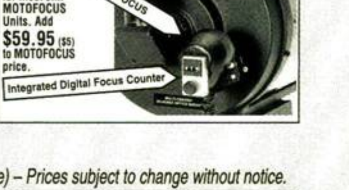

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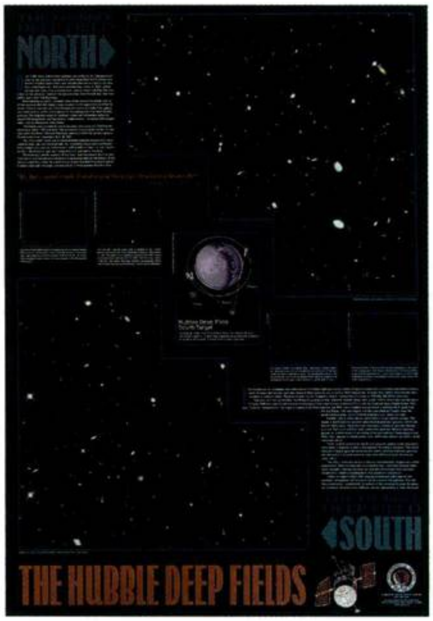
A PRODUCTS

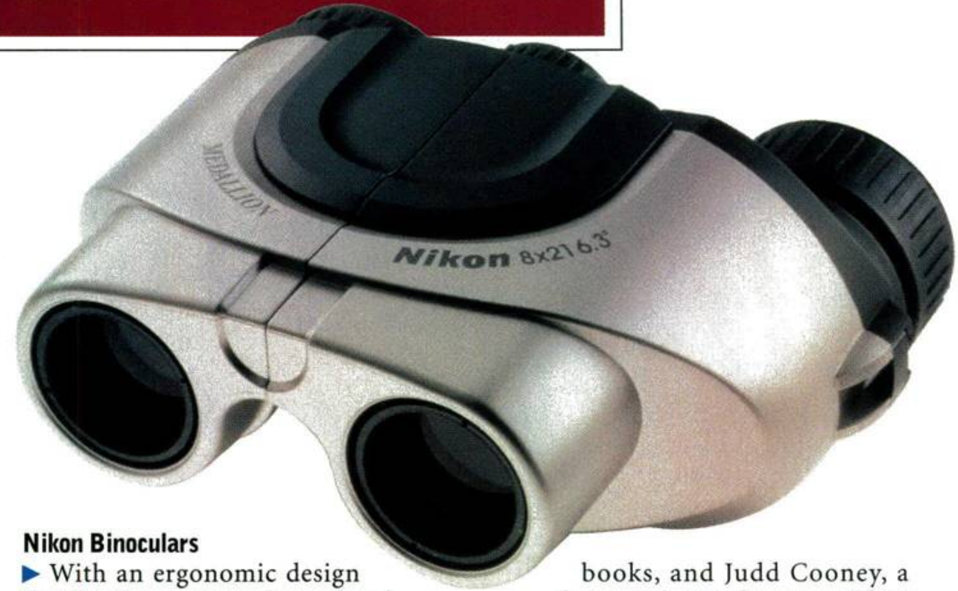
Hubble Deep Fields Poster

▶ The Astronomical Society of the Pacific now offers the first poster to highlight both the North and South Hubble Deep Fields. The 27- by 39-inch poster includes both Deep Field images as well as wide-field, ground-based photos of the targeted regions of sky. Each image is a 10-day exposure that looks down a 12-billion-light-year corridor in space. They reveal thousands of never-before-seen galaxies in a slice of the sky so tiny it represents only 1/27,000,000th of the entire night sky. This is an area approximately as small as the size of President Roosevelt's eye on a dime held at arm's length.



Accompanying the images are detailed captions describing the Hubble Deep Field project and explaining the discoveries astronomers have made from the data. The poster also includes illustrations that detail how the Hubble Space Telescope kept its gaze steady for 10 days as it collected enough light to reveal these hidden galaxies.

Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112; phone, (800) 335-2624; fax, (415) 337-5205; e-mail, catalog@aspsky.org; website, http://www.aspsky.org. Hubble Deep Fields Poster: *$14.95*



Nikon Binoculars

▶ With an ergonomic design that fits the contour of your hand, Nikon's Medallion series of binoculars offer hours of observing without user fatigue. The line also features a polycarbonate body with a brushed titanium finish. The Medallion binoculars also incorporate a diopter control for strain-free viewing, while the large central focus is easy to turn, even while wearing gloves.

The Medallion's optics include BaK4 high-index prisms and precision ground, polished lenses coated with multiple layers of antireflective compounds. They have a compact (3.5 inches by 4.5 inches) design that makes them lightweight (about 7.5 ounces) and easy to carry around in a pocket or purse.

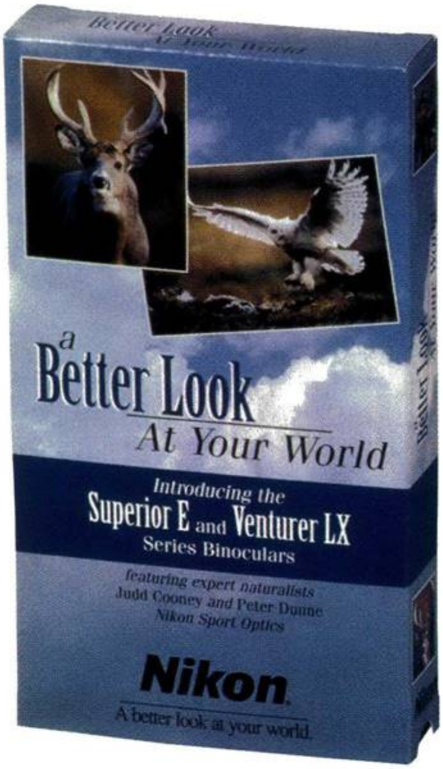
Nikon's new Travelite V series also incorporates features that make them easy to use. Like the Medallion series, Travelite uses BaK4 prisms and multi-coated lenses. These new binoculars also use aspherical eyepiece lenses, which provide a very flat viewing field that offers improved edge-to-edge sharpness.

Nikon Sport Optics, 1300 Walt Whitman Road, Melville, NY 11747-3064; phone, (800) 247-3464; website, http://www.nikonusa.com. Medallion 10 by 21: *$122.95,* Medallion 8 by 21 *(pictured): $112.95,* Travelite V 8 by 25: *$150.95,* Travelite V 9 by 25: *$160.95,* Travelite V 10 by 25: *$170.95,* Travelite V 12 by 25: *$190.95.*

Nikon Video

▶ A 15-minute VHS video titled *A Better Look at Your World* is being offered by Nikon optics. The video incorporates narrative from optics authorities Pete Dunne, curator of the Cape May Bir Observatory and author of several books, and Judd Cooney, a photographer and past president of the Outdoor Writers Association. Dunne and Cooney discuss the use of Nikon Superior E Porro prism binocular series, the Venturer LX roof prism series, and Nikon's Fieldscope III. The video also shows mechanical cutaways that describe the physical elements and capabilities of these binoculars.

Nikon Sport Optics, 1300 Walt Whitman Road, Melville, NY 11747-3064; phone, (800) 247-3464; website, http://www. nikonusa.com. A Better Look at Your World video: Free with $4.95 to cover shipping and handling.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The PulsGuide lets your eye rest between each pulse. This in turn seems to improve the contrast between the reticle and faint guide stars, making guiding easier.

PulsGuide is wireless and completely self-contained. It uses one lifelong lithium battery, which is supplied and features two independently controlled on/off pulse timing knobs as well as a brightness switch. Astroimagers can choose either a red or yellow light: Many astro-imagers have found low-level yellow light improves visual acuity over red.

Should you choose not to purchase the guiding eyepiece, PulsGuide fits a standard 8mm threaded hole. Adapters are available for 10mm or 14mm threaded, set-screw holes.

Rigel Systems, 26850 Basswood Avenue, Rancho Palos Verdes, CA 90275; phone and fax, (310) 375-4149; e-mail, rigelsys@ix.netcom.com; website, http://pw2.netcom. com/~rigelsys/rigelsys.html. PulsGuide: *$39.93 plus shipping and handling,* PulsGuide with guiding eyepiece (12mm Kellner): *$119.95.*

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A BOOKS

Journey Beyond Selene

Jeffrey Kluger, 315 pages, Simon & Schuster, New York, 1999; ISBN 0-684-84765-5; hardcover, $26.

A funny thing happened when our robotic emissaries explored other planets. Their moons, in some respects, were more interesting.

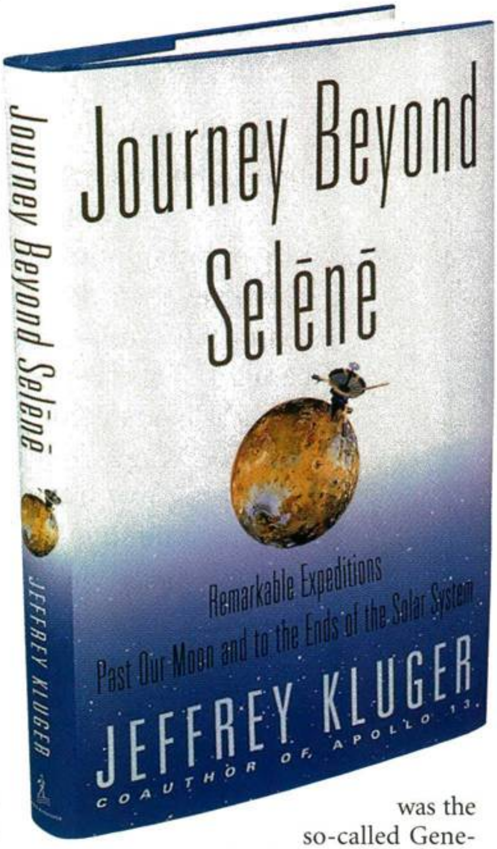
In *Journey Beyond Selene*, Jeffrey Kluger, a senior writer at *Time* magazine and co-author with astronaut Jim Lovell of a bestselling book about Apollo 13, takes us on trips of serendipitous discovery that occurred largely out of the media spotlight. As the book's title suggests (Selene is the Greek goddess of the moon), it's a story of humanity's first look at Earth's moon and the moons around Jupiter, Saturn, Uranus, and Neptune. Kluger describes the people and the missions that made the discoveries possible.

The book divides itself into two parts. The first half covers the largely untold story of Project Ranger of the early 1960s. This is an important story because Project Ranger was NASA's first unabashed attempt at robotic exploration and the first robotic lunar landing. It was a baptism by fire for the now-famous Jet Propulsion Laboratory (JPL).

The program's goal was to return TV pictures right up until the moment of lunar impact. But the first six Ranger flights failed. Ranger 6's TV cameras, for example, never turned on as it crashed. Instead, as Kluger recounts in the chapter "Splendid Suicide," everyone in JPL's control room and around the country heard a woman urging them to, "spray on Avon cologne mist and walk in fragrant beauty." Somehow, a commercial radio station signal found its way into the feed from NASA's ground station in Goldstone, California.

Despite the problems with the early Ranger missions, Rangers 7, 8, and 9 were stunning successes. They gave scientists a rough idea of what the moon's geology was like, and, most importantly, they practically confirmed that the lunar surface was solid enough to support a manned lander.

Kluger then fast-forwards the reader to Apollo 15. This mission was far more ambitious in scope than Apollos 11, 12, and 14. The astronauts stayed on the surface longer; they drove around in a lunar dune buggy; and they returned more rock samples. One of the samples was the so-called Genesis Rock, which dates back to the beginning of the solar system.



In the second half of the book, Kluger treats readers to a tour of the outer solar system's moons courtesy of Voyagers 1 and 2. Up until the 1970s and 1980s, these moons were largely featureless blips even as seen in the largest telescopes. Thanks to the Voyagers, we now see each of these moons as unique worlds almost as complex as the planets themselves.

Kluger presents an insider's story of seeing these worlds up close for the first time. He also gives us snippets of what it was like to pull off a mission

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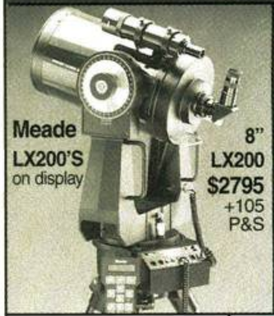
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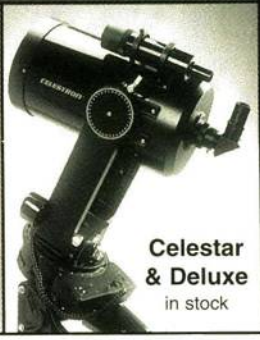
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such as Voyager, from the 1966 discovery by a Caltech graduate student Michael A. Minovitch of a "Grand Tour" trajectory that occurs every 176 years, to Voyager 2's last planetary family photo in 1991 taken from beyond the orbit of Neptune.

The book's final chapter shares some of the excitement and results from the first two years of Galileo's mission to the jovian system. It also previews what scientists might learn when the European probe Huygens parachutes to the surface of Saturn's large moon Titan in 2004. Kluger even speculates about what a proposed JPL mission to Pluto might see when it flies by Pluto's moon Charon.

Like any overenthusiastic yarn spinner, Kluger at times gets carried away with hyperbole. About Voyager, he writes, "Never mind that there were a thousand wrong turns the ship could make, and if it made just one of them it would spin off into the void, never to contact Earth again." Truth is, Newtonian physics was rather mundanely in control the whole time, with ground controllers making only periodic engine burns and the slightest of corrections to optimize flybys.

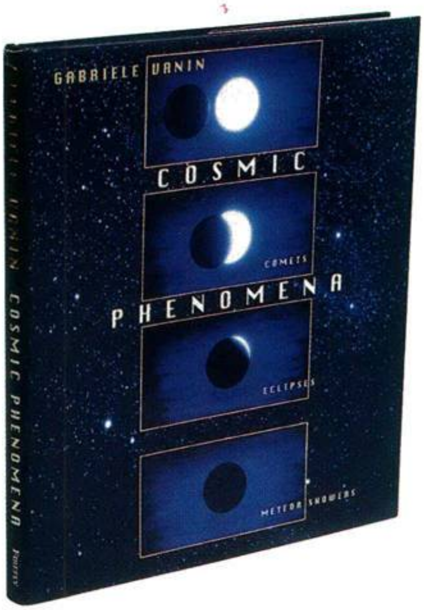
The book also holds an error in the appendix that lists Rangers 1 and 2 as unsuccessful moon probes. Both missions were engineering tests that failed to reach their intended high-Earth orbit, a fact Kluger does keep straight in the main text.

These minor points aside, I found Kluger's treatment up to the task of recording our discovery of worlds around planets. *Journey Beyond Selene* is an entertaining and eye-opening read.
— John Shibley, contributing editor

Cosmic Phenomena

Gabriele Vanin, 167 pages, Firefly Books, Willowdale, Ontario, 1999; ISBN 1-55209-423-5; hardcover, $35.

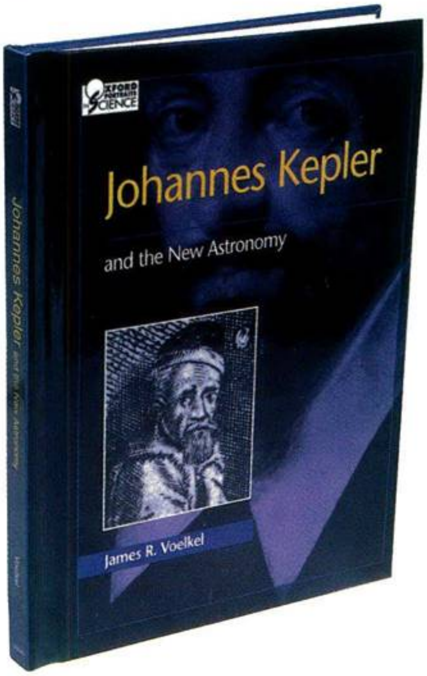
▶ Italian astronomer Gabriele Vanin presents a highly accessible and lavishly illustrated guide to some of the great celestial phenomena that can be viewed with the naked eye. The first section discusses comets, with emphasis on Comet Hyakutake and Comet Hale-Bopp. The second section covers meteor showers and meteor storms. The final section looks at solar and lunar eclipses.



Johannes Kepler and the New Astronomy

James R. Voelkel, 144 pages, Oxford University Press, New York, 1999; ISBN 0-19-511680-1; hardcover, $21.

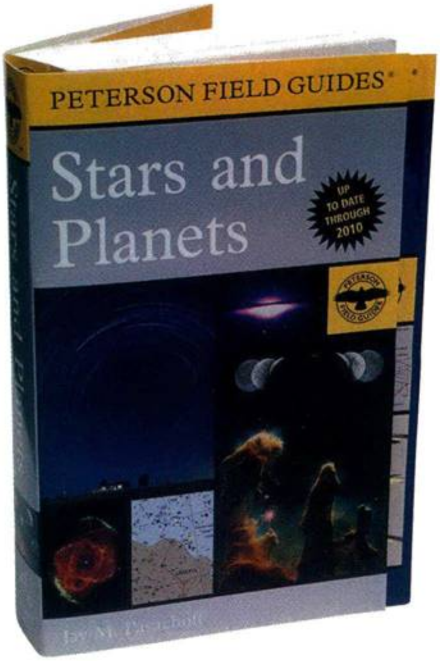
▶ This newest installment of the Oxford Portraits in Science series covers the great astronomer who unlocked the secrets of planetary orbits. Written for young adults, the narrative is highly accessible and engaging, and it gives the reader a real flavor for Kepler's life and times.



A Field Guide to the Stars and Planets, Fourth Edition

Jay M. Pasachoff, 512 pages, Houghton Mifflin Company, Boston, 2000; ISBN 0-395-93432-X (hardcover), ISBN 0-395-93431-1 (paperback); $30 (hardcover), $19 (paperback).

▶ The latest installment from the popular Peterson Field Guides series contains new star maps that are completely updated through 2010. For the first time in this series, the maps are printed in color, making them easier to use. *Stars and Planets* is loaded with information, tables, and charts about the solar-system and deep-sky objects. It's an excellent starting point for newcomers to amateur astronomy and a handy reference for well seasoned observers.



Unfolding Our Universe

Iain Nicholson, 269 pages, Cambridge University Press, New York, 1999; ISBN 0-521-59270-4; hardcover, $35.95.

▶ This comprehensive introduction to astronomy covers topics ranging from the nature of light and telescopes to cosmology and the question of life. The text, by British popular astronomy writer Iain Nicholson, is clear and concise, and the book is richly illustrated with color photos and diagrams.

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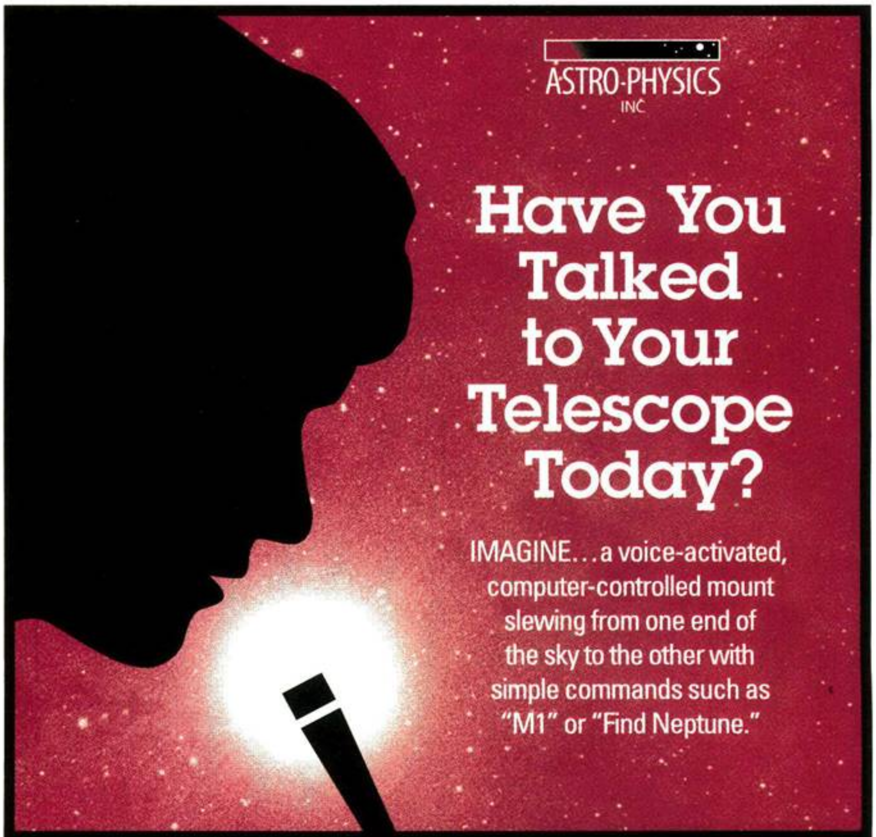
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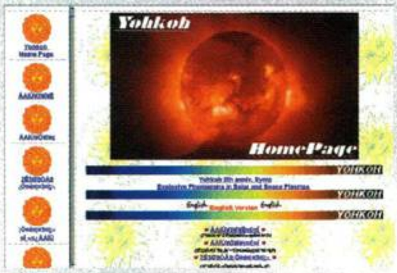
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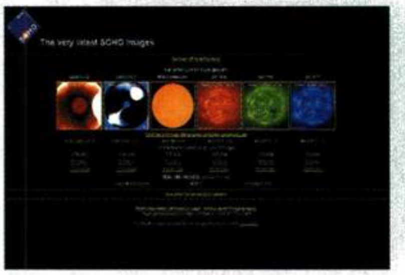
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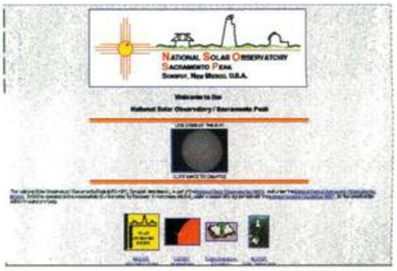
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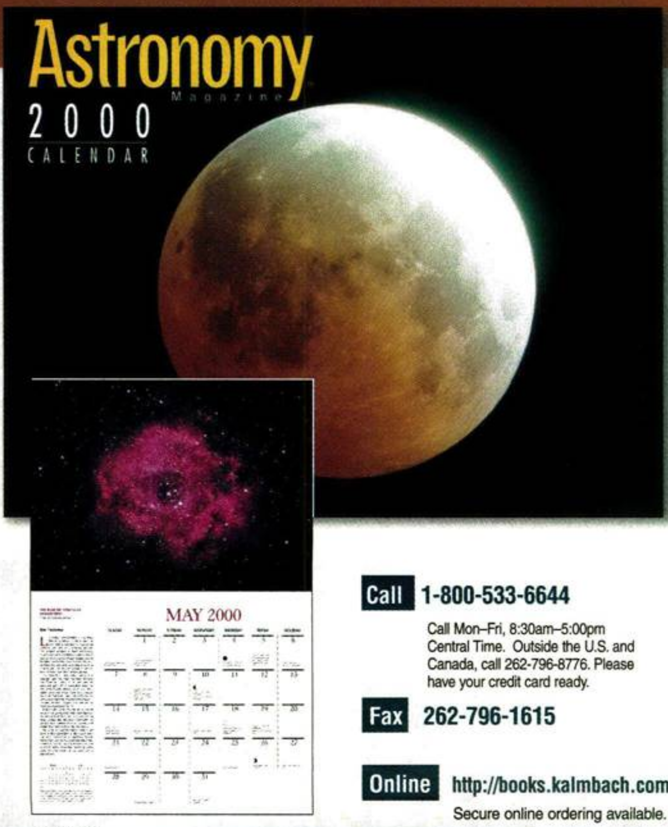

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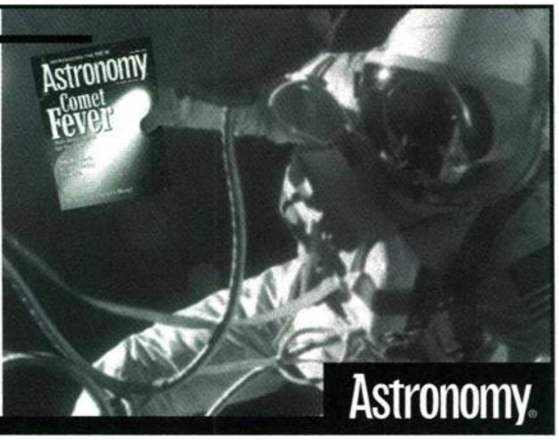

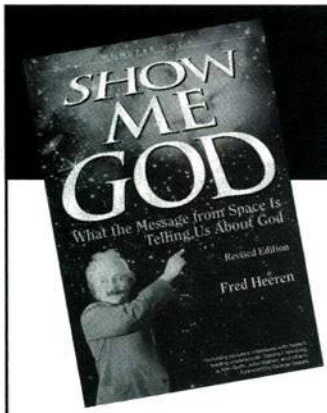

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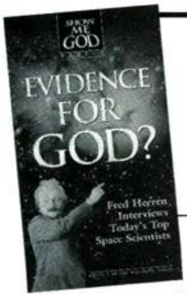

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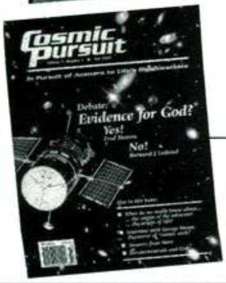

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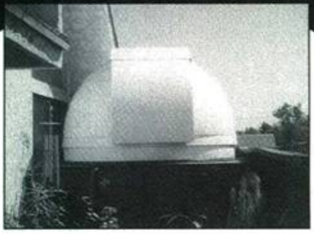

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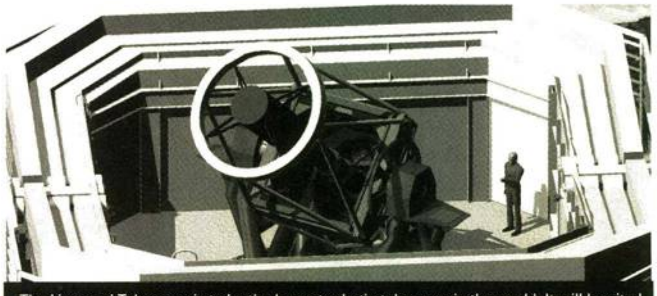

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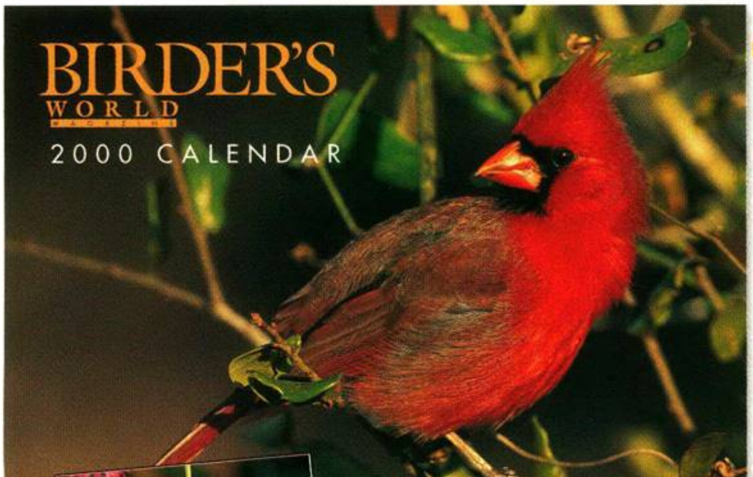

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JANUARY

Astronomy

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JANUARY 5–9

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▶ Molokai Ranch, Paniolo Camp, Molokai, Hawaii. Hosted by the Hawaiian Astronomical Society and LITEBOX Telescopes. Contact Barry Peckham, 1415 Kalakaua Avenue, Suite 204, Honolulu, HI 96826; (808) 955–0095; e-mail, bpeck@aloha.net; Molokai Ranch website, http://www.aloha.net/~bpeck/Molokai_Ranch/index.html.

JANUARY 11–15

195th Meeting of the American Astronomical Society

▶ Hyatt Regency, Atlanta, Georgia. Hosted by Georgia State University. For information on scientific programming or exhibit information contact Diana Alexander, (202) 328–2010; e-mail, diana@aas.org; for registration information contact Millie Durbin, (202) 234–7850; e-mail, reg-help@aas.org; AAS website, www.aas.org.

JANUARY 26

The Silicon Valley Astronomy Lecture Series — Alex Fillipenko: Einstein's Biggest Blunder: New Discoveries about Cosmic Antigravity

▶ Smithwick Theater, Foothill College, Los Altos, California. 7 P.M. Free. Sponsored by NASA's Ames Research Center, Foothill College, the SETI Institute, and the Astronomical Society of the Pacific. Call (650) 949–7888 for more information.

JANUARY 31–FEBRUARY 5

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▶ Camp Wesumkee, West Summerland Key, Florida Keys. Sponsored by the Southern Cross Astronomical Society. For information, contact registrars Fred and Lucille Heinrich, 6165 Wiggins Road, Live Oak, FL 32060; (904) 362–5995; fax, (904) 362–5996; e-mail, Heinrich@alltel.net; website, www.scas.org. For information about accommodations call 1–800–FLA–KEYS.

FEBRUARY 2–6

Orange Blossom Special Star Party

▶ Hickory Hill Observing Complex, near Brooksville, Florida. Sponsored by the St. Petersburg Astronomy Club. Contact Dennis and Ellen Farr, 8811 West Broad Street, Tampa, FL 33615; (813) 884–9111; e-mail, dnefarr@aol.com.

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CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com. Look for additional events at http://www.astronomy.com.

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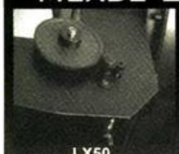
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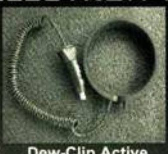
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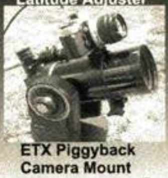
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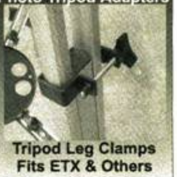
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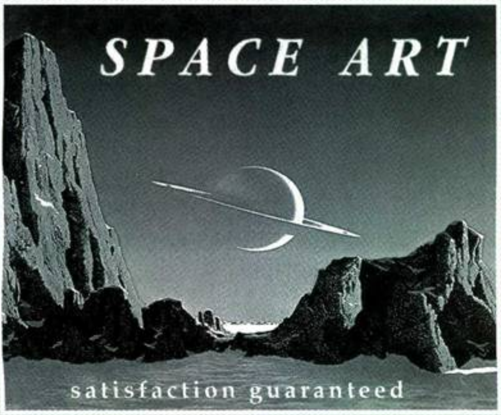

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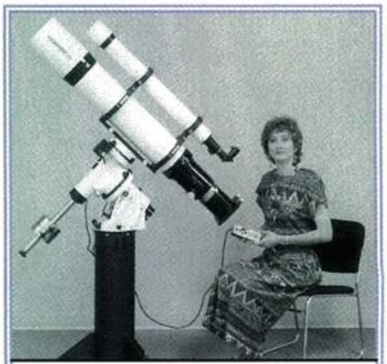

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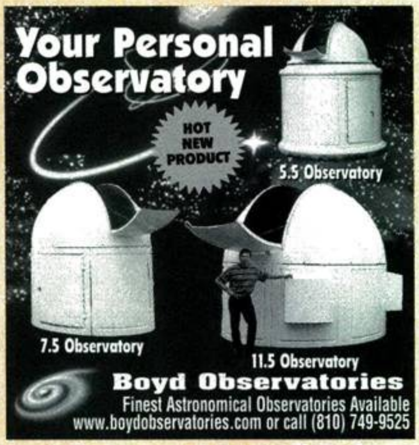

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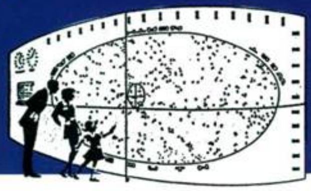

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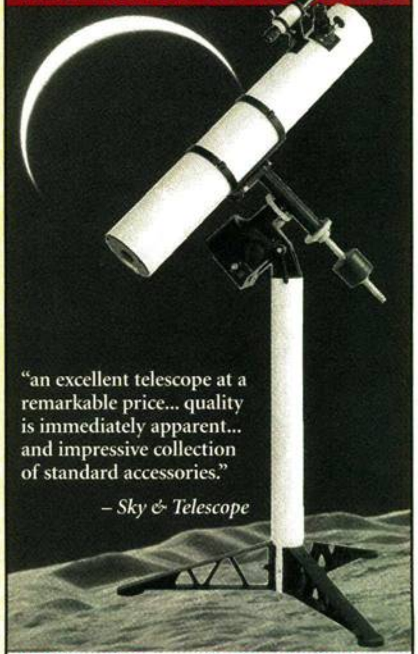

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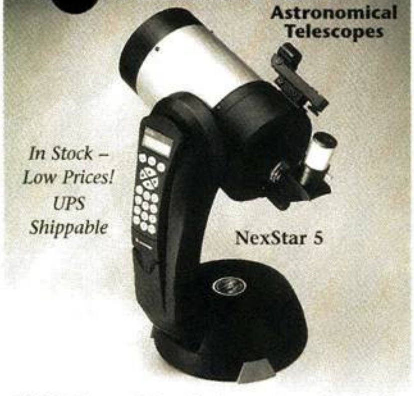

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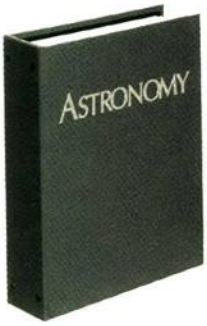

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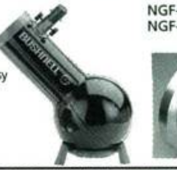

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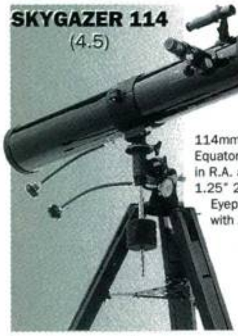

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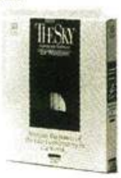

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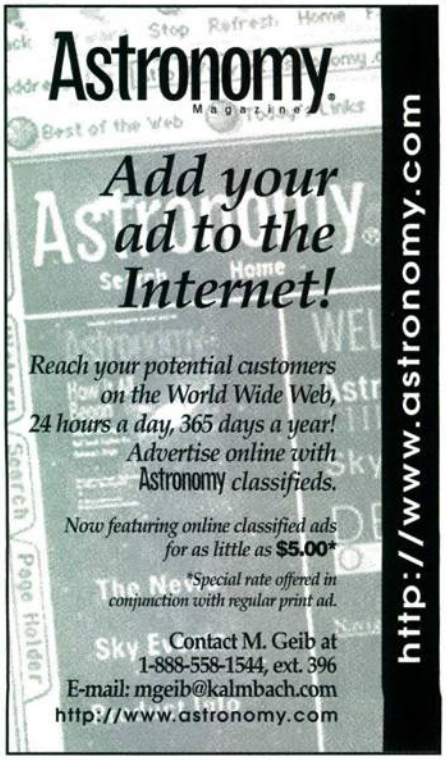

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A. Total number of copies (net press run)	274,469	259,142
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1. Sales through dealers and carriers, street vendors, and counter sales	57,693	57,869
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I. Total (sum of 15G, 15H1, and 15H2)	274,469	259,142
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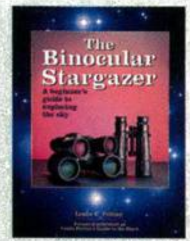
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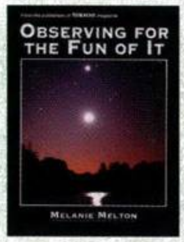
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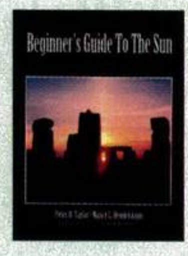
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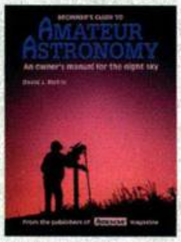
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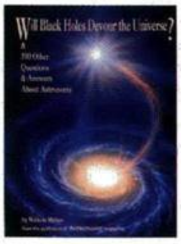
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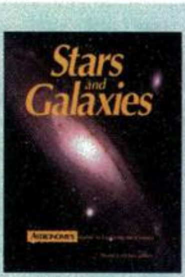
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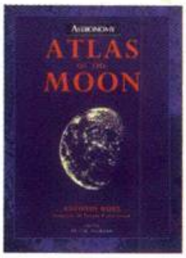
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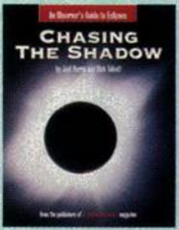
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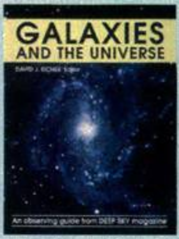
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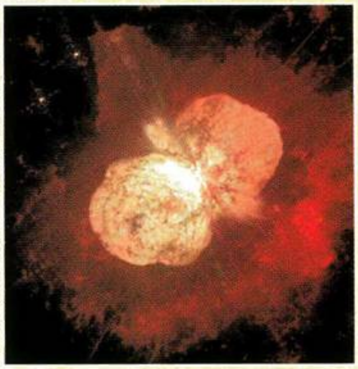
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SOLAR ECLIPSE

The Race for Darkness

► *One month before eclipse day* — My wife, Nancy Hicks, and I, who live in suburban Boston, plan a two-week trip to Cornwall, England, to see the eclipse with her relatives who live there. Unfortunately, we cancel because we are unable to stay for that long.

August 2 — I drive home from work envisioning taking in the television coverage of the eclipse in a little more than a week. I cannot stand it any longer.

August 2, later — We now hold round-trip reservations to Paris, arriving August 11 and leaving back for Boston the same day. One day turnaround. Crazy, you say? Sure. But we are eclipse chasers.

August 10, 6:10 P.M. — American Airlines Flight 146 leaves Boston's Logan Airport bound for Paris. The weather is iffy. We know that France was never supposed to be the best place to go for this eclipse.

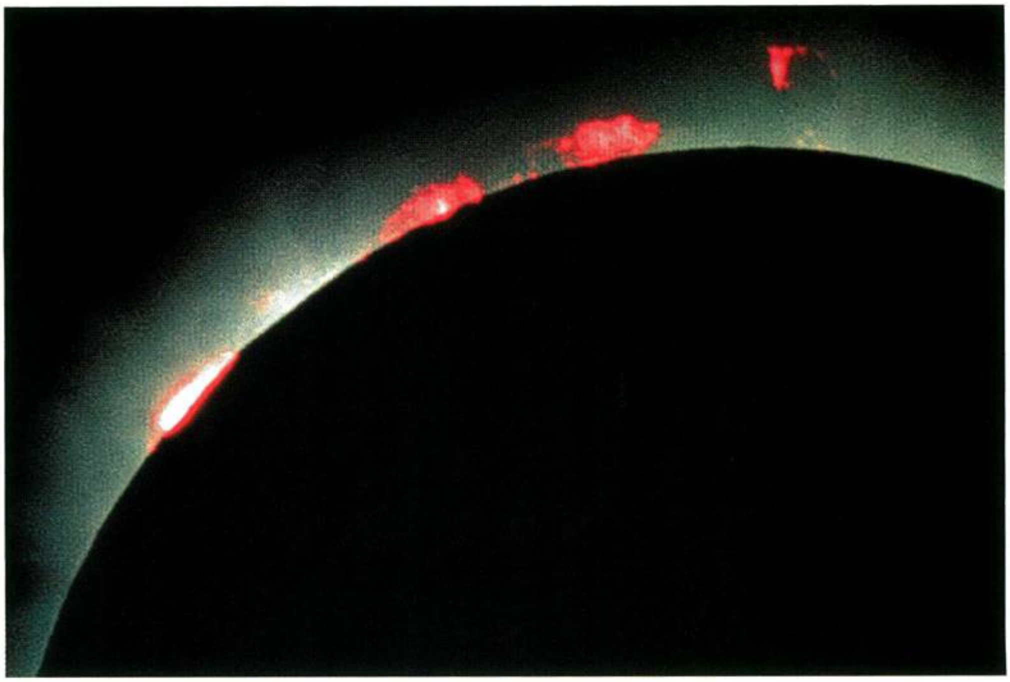
August 11, 6:30 A.M. — Flight 146 arrives at Paris-Orly. With totality set for 12:20, we need to get at least 20 miles north of Paris and find a noncloudy spot. As we arrive, it has just stopped raining. We need to lose the clouds, fast.

7:00 A.M. — We are met by our chauffeured, air-conditioned Renault sedan, completely equipped with Rudy, our bilingual maniac driver, bottles of juice and Evian, two boxes of cookies, and a cellular phone.

Top: The Last Minute Eclipse

JOSEPH HOROWITZ

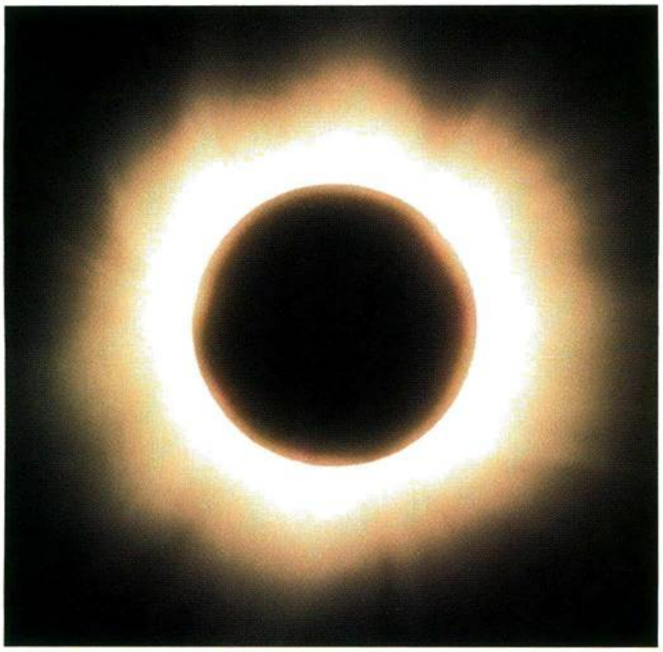
(Joseph, Nancy Hicks, and their driver Rudy speed across the French countryside to catch the millennium's last solar eclipse.)



Above: Zooming in on the Sun

OLTOLINI ALBERTO

(1000mm lens at f/10, Fuji Velvia ISO 50 slide film, 1/125-second exposure)



Left: The Sun's Crown

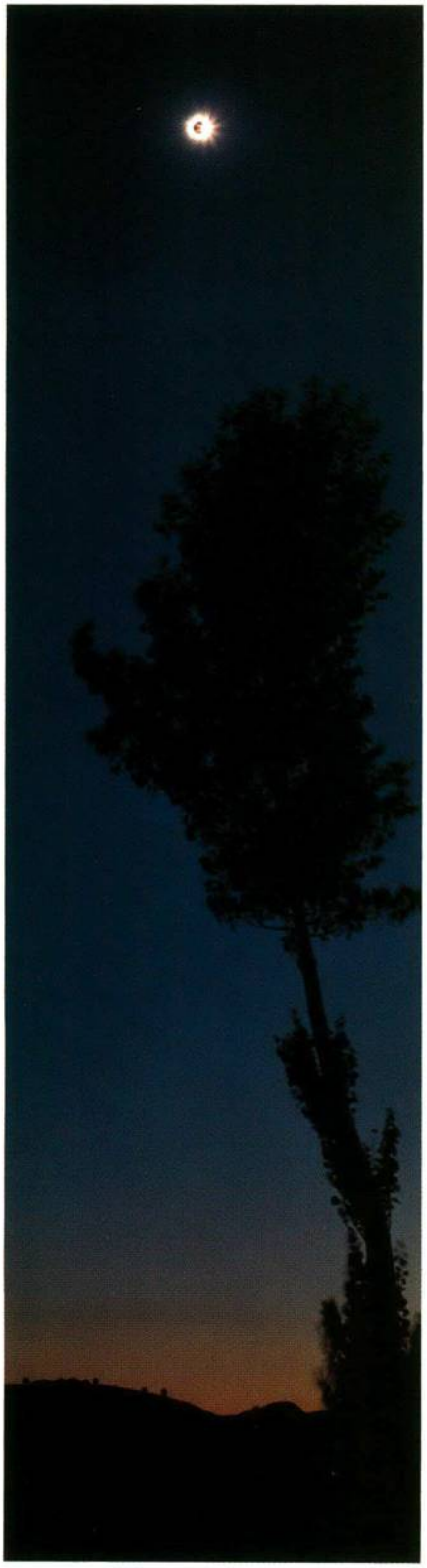
SCOTT JOHNSON

(5-inch f/6 refractor, Fuji Reala 100 film, 3-second exposure)

7:15 A.M. — A quick call to AccuWeather, back in Pennsylvania, determines that it is cloudy over much of France. But if we go northwest toward the coast of Normandy, we have a chance. The clouds could break up at the coast by mid to late morning. The closer to the coast, the better.

11:30 A.M. to Show Time— We stop in a village 30 miles from the coast after hours of driving. The partial eclipse is already under way, and the sky is half covered with clouds. We now race to the coast because, should there be any question there, we could race back this way. As we get closer to the coastal area, it is not at all obvious that it will be clear there. It is less than 30 minutes to totality. We zip around a traffic circle and head back from whence we came. Hot on our heels, the clouds from the coast are chasing us.

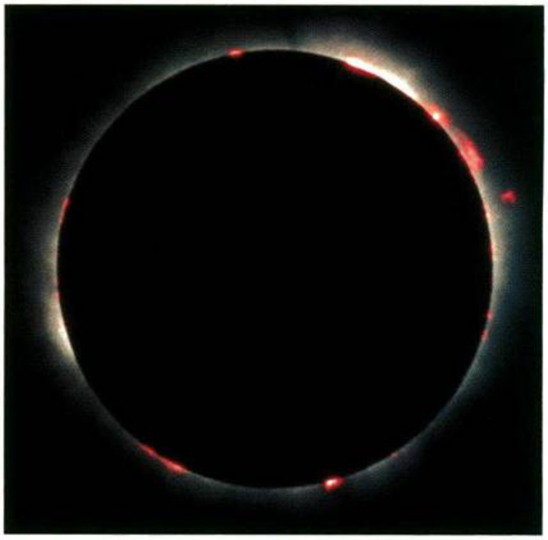
It is now 20 minutes to totality. We stop in a sunny spot. This is it. This is our site. Minutes later the coastal clouds overtake us. This is not it. We race on away from the coast. We stop again and again. Pulloffs along this road near the centerline are crowded with people gazing skyward. Each time — this is it, this is our site. Each time, the coastal clouds overtake us. Less than 10 minutes to totality. We push on. Clouds ahead, clouds behind. Partial blue skies to the left. Rudy, take this left; too late; take the next one; missed too; take the next one. The little lane goes straight, past a charming French country house and then, with 5 minutes to go until totality, into a deep woods. Of all the ways to miss an eclipse. We drive as fast as we can,



A Diamond Ring over Turkey

JOHN POST

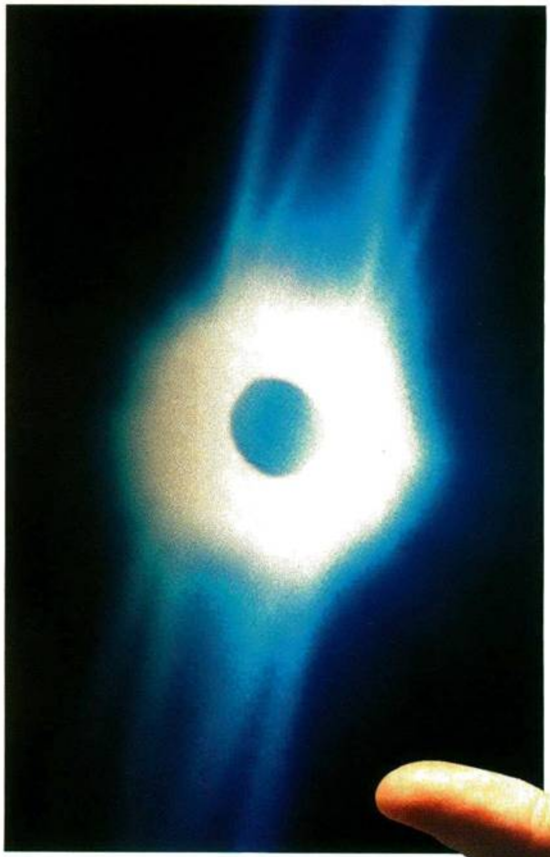
(105mm lens at f/16, Agfa Ultra ISO 50 film, 6-second exposure)



Leaping Prominences

ALLISON AND MICHEL BENVENUTO

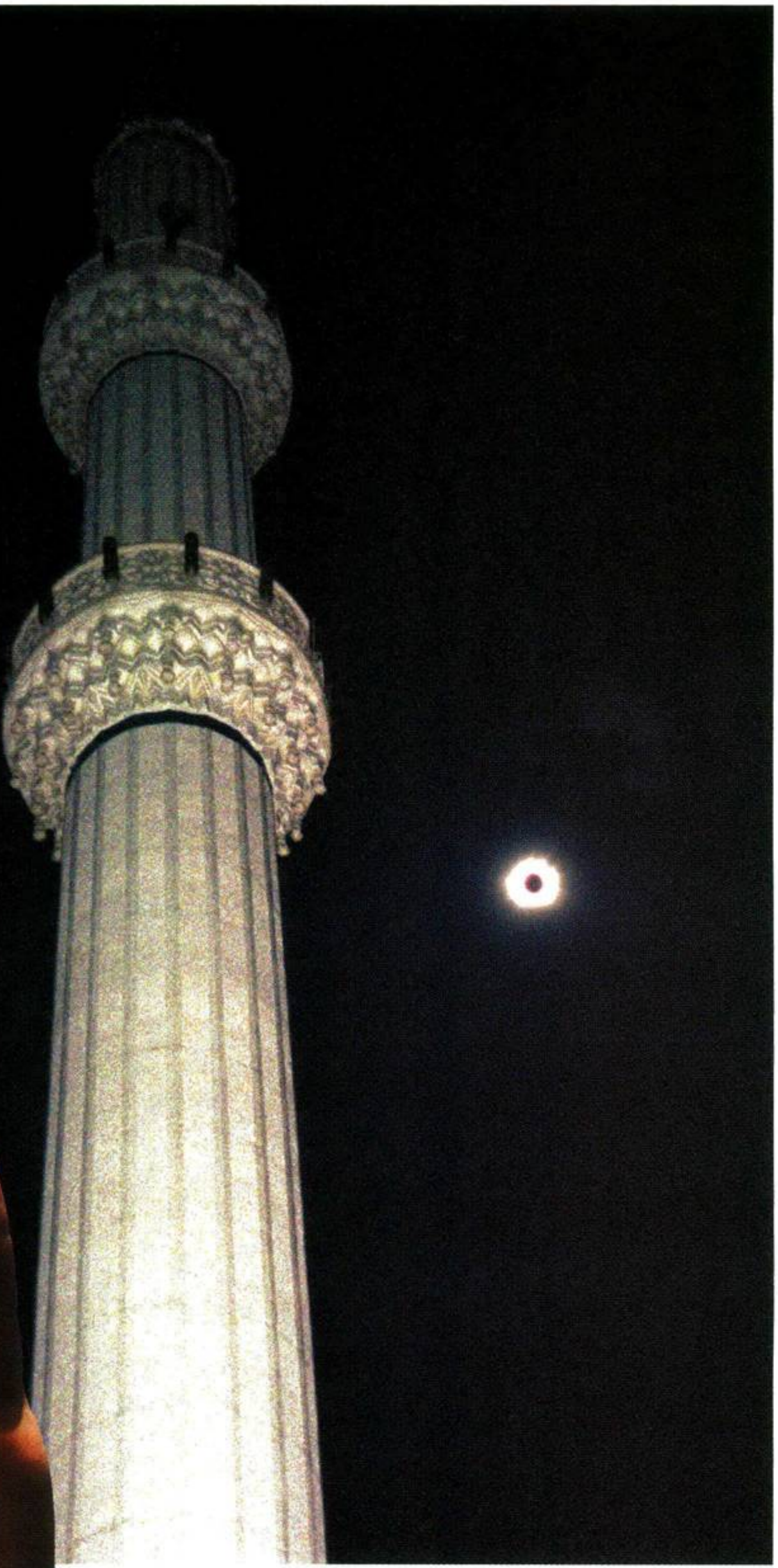
(400mm lens at f/11, Kodak EliteChrome Select ISO 100 film, 1/250-second exposure)



Giant Coronal Streamers

YAVOR SHOPOV

(taken from a military fighter cruising at 40,000 feet; shot on color infrared film)



Turkish Minaret by Eclipsed Sun

BRIAN JUST

(38mm lens, Fuji ISO 200 film, taken at Cami Beyazit in Osmancik, Turkey)

Capturing the Partial Phase

PIERRE SCHINTONE

(55mm lens at f/8, Kodak Ektachrome ISO 100 film, 1/125-second exposure)

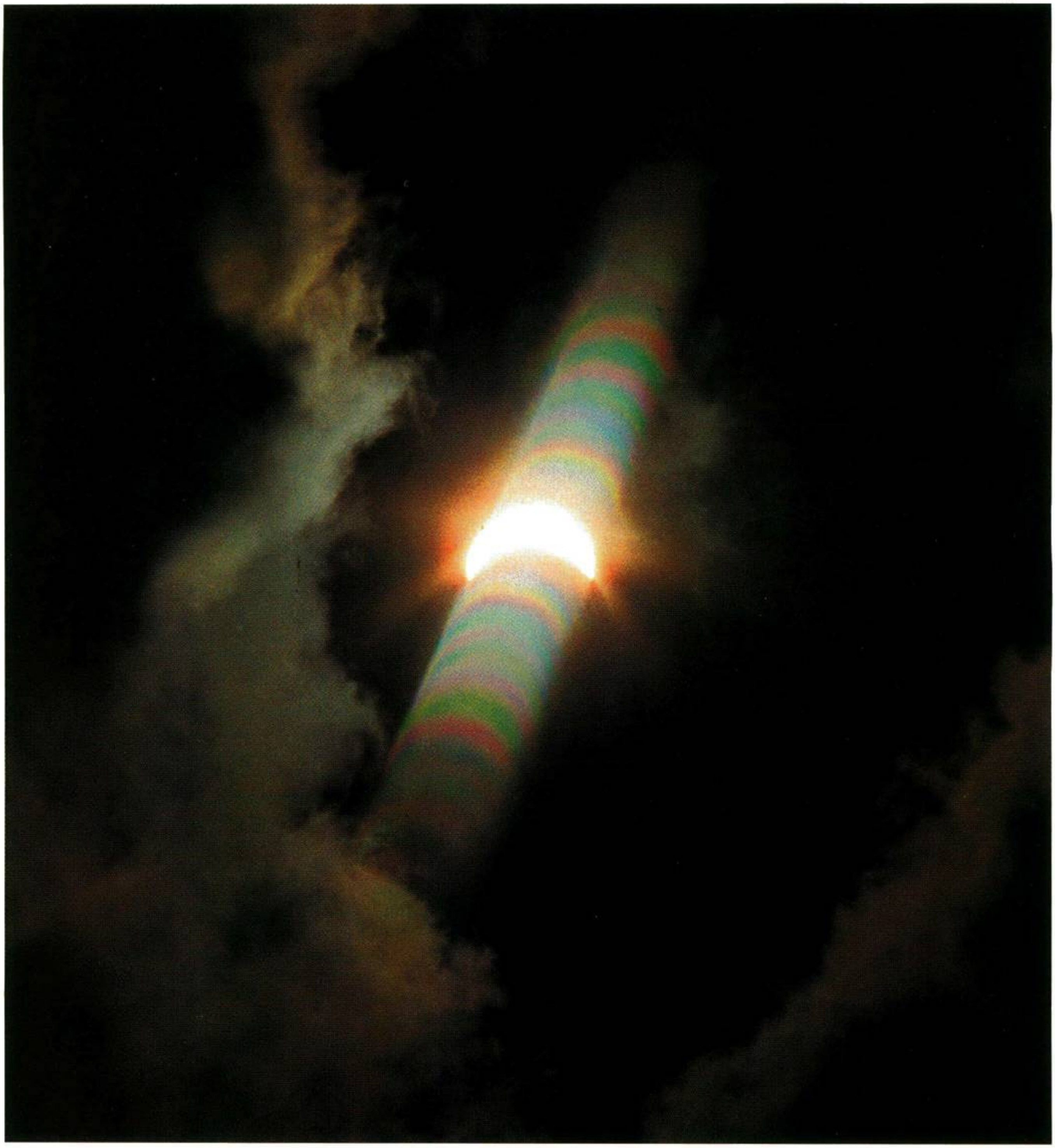
hoping the woods will end, and as if in answer to our prayers, break out into a lovely country valley. Three minutes to totality. Blue skies above. Voila! No more time. Rudy screeches the car to a halt on the edge of a farmer's field. We run up to join a handful of locals.

A rooster crows the impending "night." A great curtain robs much of the remaining light in nearly an instant. The temperature drops noticeably. The last sliver of sun grows smaller and smaller. A flash of light on the left side of the sun, a magnificent diamond ring. And then . . . totality! Beautiful coronal streamers. And oh, the prominences. We count seven naked-eye prominences — fiery red-orange protuberances from the sun, one seemingly detached. Venus in the darkness below the sun. Sunset colors are on the horizon of this dramatic, hilly landscape. Two minutes go by very quickly. A stunning diamond ring appears on the right side of the sun, as the moon moves away. Totality is over. A thin sliver of sun returns, ever growing. We did it.

Postmortem — We find out that the price of chasing so far out in the French countryside was not getting back in time. (This, despite heroic efforts by our "Grand Prix" driver.) We are "forced" to stay in Paris overnight and enjoy three wonderful French meals and Parisian hospitality before returning to Boston, one day later than planned.

Total time elapsed — 53 hours. ■

Joseph L. Horowitz works for the U.S. Army Corps of Engineers in New England.



The Last Solar Eclipse of the Century

BERND EICKHOFF

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The Whirlpool Galaxy (M51) in Canes Venatici. Photographed with a Meade 10" f/10 LX200 Schmidt-Cassegrain Telescope in southern France by Philip Perkins of Wiltshire, England. Mr. Perkins used two exposures of 120-mins. each on hypered Kodak Ektapress Multispeed PJM-2 film; these exposures were then scanned, digitally combined, and processed to obtain the final image.

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